

**Assessment of Cabin Dimensions to Accommodate Infantry  
Soldiers for the Future Vertical Lift/Joint Multi-Role  
Medium-Class Aircraft**

**by David B. Durbin, Jim A. Faughn, Richard W. Kozycki, Jamison S. Hicks,  
and Ron L. Carty**

**ARL-TR-6988**

**July 2014**

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# **Army Research Laboratory**

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**ARL-TR-6988****July 2014**

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**Human Research and Engineering Directorate, ARL**

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## **Executive Summary**

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An assessment was conducted to determine the minimum cabin dimensions to accommodate infantry Soldiers for the Future Vertical Lift/Joint Multi-Role medium-class aircraft. The assessment was conducted 12–13 September 2012 at the Maneuver Center of Excellence, Maneuver Battle Laboratory, Fort Benning, GA, using a lumber and plywood cabin mockup. The mockup consisted of adjustable Plexiglas seat space dividers, an adjustable mesh cabin ceiling, reconfigurable benches, two adjustable-width doors (left and right) at the front of the mockup, and an aft ramp. Adjustability of the cabin ceiling, seat space dividers, door widths, and benches allowed assessment of different interior dimensions to evaluate space requirements for groups of 9, 14, and 18 Soldiers with combat gear. The interior dimensions assessed included seat space widths, cabin ceiling heights, aisle widths, seating configurations, and cabin door widths. Emergency egress trials were conducted to assess the impact of cabin ceiling height on the ability of Soldiers to quickly and safely exit the aircraft.

### **E.1 Seat Space Widths**

The seat space widths that were assessed included 20.0, 22.0, 23.0 (large Soldiers only), 24.0, and 26.0 in. Fit was very tight for the largest Soldiers in the 20.0-in. seat space. The majority of Soldiers reported that upper-body, arm, leg, and foot movement was restricted in the 20.0-in. seat space. Most Soldiers had to maintain a confined and static seating position and did not appear to have adequate space to effectively reposition their upper torso, arms, legs, and feet to minimize fatigue when seated in the 20.0-in. seat width. The Soldiers reported less restriction of upper-body, arm, and foot positioning for the 22.0-in. seat space with (about) half of the Soldiers reporting that leg movement was restricted. The majority of large Soldiers reported that upper and lower-body movement was restricted at 22.0 in. The three large Soldiers used to assess the 23.0-in. seat space reported moderate upper-body restriction and commented that it would be the minimally acceptable seat space width if they were seated next to other large Soldiers. Most Soldiers reported that upper-body, arm, leg, and foot movement was not restricted for the 24.0- or 26.0-in. seat space.

### **E.2 Cabin Ceiling Heights**

The cabin ceiling heights that were assessed included 54.0, 60.0, 66.0, and 72.0 in. All Soldiers had to significantly bend their torso and knees and adopt a stooped posture during ingress and egress at the cabin ceiling height of 54.0 and 60.0 in. The larger Soldiers had to adopt a very stooped posture to ingress (and egress) the cabin at 54.0 and 60.0 in. The stooped posture combined with most Soldiers being top-heavy (due to weight of their gear on their torso) increases the probability that they would lose their balance and fall during ingress and egress. The weight of the combat gear that the Soldiers wore during the assessment ranged from 57

(60-mm assistant gunner) to 99 lb (assistant gunner). The stooped posture also increases the probability of lower back strain. At the 54.0-in. ceiling height, one Soldier tripped and fell (in the aisle) during egress, and the night vision goggle mount on the helmet of one Soldier struck the cabin ceiling, which caused his head to be jerked back during egress. The majority of Soldiers inadvertently pushed their helmet and/or upper back through the cabin ceiling netting during ingress and egress at the 54.0-in. ceiling height due to the very limited vertical space between the ceiling and the cabin floor. At the 60.0-in. ceiling height, the larger Soldiers inadvertently pushed their helmet and/or upper back through the cabin ceiling netting during ingress and egress. The majority of Soldiers reported that it was difficult to carry and maneuver their gear at the 54.0- and 60.0-in. heights. Loading litters, supplies, and equipment would also be difficult and time-consuming at the 54.0- and 60.0-in. heights due to the limited vertical space to maneuver in the cabin. The Soldiers were able to stand more upright at the 66.0-in. ceiling height, and the majority reported they experienced no difficulty when carrying and maneuvering their gear during ingress. Eighty-eight percent (N = 16) of the Soldiers reported that they did not have to bend their torso and knees (or adopt a stooped posture) during ingress at the 72.0-in. cabin ceiling height. They reported that it was not difficult to carry and maneuver their gear during ingress. Ingress and egress times were progressively faster as the cabin ceiling heights were raised to higher positions.

### **E.3 Floor Widths**

Floor widths of 68.0 and 72.0 in. were evaluated during the assessment. Aisleway widths were 33.0 in. for the 68.0-in. floor width and 37.25 in. for the 72.0-in. floor width. At the 68.0-in. floor width, leg movement and positioning of feet was restricted for most of the Soldiers. The Soldiers could not traverse the aisleway due to lack of space for foot placement. When the benches were configured for a floor width of 72.0 in., the largest Soldier was able to traverse the aisleway with difficulty (due to restricted space for foot placement). The majority of Soldiers reported that the difficulty of ingress was “about the same” for the 68.0-in. floor width versus the 72.0-in. width. About half of the Soldiers reported that the difficulty of egress was more difficult for the 68.0-in. floor width versus the 72.0-in. width.

### **E.4 Fore and Aft Seating Configuration**

In the fore and aft seating configuration, the groups of 9 and 14 Soldiers were able to ingress and egress the cabin and fit in their allotted seat space. The majority of Soldiers reported that their upper-body movement was not restricted but that their leg movement and foot positioning was restricted.

### **E.5 Cabin Door Widths**

The largest male Soldier performed ingress and egress trials through the right front cabin door. The height of the door was 72.0 in. The width of the door varied between 28.0, 32.0, and 36.0 in. for the trials. He had to assume a slightly stooped posture during the trials to ensure that he did

not strike his helmeted head against the bottom of the upper door frame. The Soldier had to progressively draw his shoulders and arms inward to his chest (more) as the door width was decreased from 36.0 to 32.0 to 28.0 in. At the 28.0-in. door width, the ammo pouch on his right side contacted the side of the door frame.

## **E.6 Emergency Egress**

The emergency egress requirement of 60 s (or less) was met for all groups of Soldiers and cabin ceiling heights. The average emergency egress times were 7–19.5 s.

## **E.7 Recommendations**

Recommendations for the minimum cabin dimensions are 23.0 in. for seat spacing, 66.0 in. for cabin ceiling height, 72.0 in. for floor width, and 32.0 in. for door width. These dimensions will help ensure that Soldiers have adequate space to effectively reposition their upper torso, arms, legs, and feet to minimize fatigue when seated, carry and maneuver their gear during ingress and egress, safely and quickly ingress and egress the cabin, and load supplies and equipment in the cabin.

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# **1. Introduction**

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## **1.1 Purpose**

The U.S. Army Research Laboratory's Human Research and Engineering Directorate (ARL-HRED) and the U.S. Army Aviation and Missile Research, Development and Engineering Center's Aeroflightdynamics Directorate (AFDD) conducted a space claim assessment for infantry Soldiers to determine the minimum acceptable cabin dimensions for design of the Future Vertical Lift/Joint Multi-Role (FVL/JMR) medium-class aircraft. The assessment supported development of the medium-class model performance specification. FVL/JMR represents a family of air vehicle classes that include light, medium, heavy, and ultra-heavy. This assessment focused on the medium-class air vehicle, which will have a capacity of 9–18 passengers. The assessment was conducted 12–13 September 2012 at the Maneuver Center of Excellence (MCoE), Maneuver Battle Laboratory (MBL), Fort Benning, GA, using a lumber and plywood cabin mockup. Eighteen infantry Soldiers assigned to the MBL Experimental Force participated in the assessment to evaluate seat space widths, ingress/egress times for various cabin configurations, ceiling height, door widths, and cabin configuration requirements. The assessment augmented modeling of space requirements for infantry Soldiers previously conducted by ARL-HRED in support of AFDD.

## **1.2 Cabin Mockup**

The FVL/JMR medium cabin mockup (figure 1) was used to conduct the assessment. The mockup was designed by AFDD and ARL-HRED and built by the Prototype Integration Facility at Redstone Arsenal, AL. It was constructed of lumber and plywood and consisted of adjustable Plexiglas seat space dividers, an adjustable mesh cabin ceiling, reconfigurable benches, two adjustable-width doors (left and right) at the front of the mockup, and an aft ramp. Adjustability of the cabin ceiling, seat space dividers, door widths, and benches allowed assessment of different interior dimensions to evaluate space requirements for groups of 9, 14, and 18 troops with combat gear. The seat space dividers were adjusted to 20.0, 22.0, 23.0 (large Soldiers only), 24.0, and 26.0 in. to assess seat width requirements. The ceiling was adjusted to 54.0, 60.0, 66.0, and 72.0 in. to assess restrictions on time and ability to ingress and egress the mockup, Soldier posture, and seated height limitations. Benches were initially located along the cabin walls to replicate a ramped configuration to assess troop seat spacing, cabin floor width, aisleway space, and troop gear/pack stowage. The benches were moved inboard to evaluate alternative cabin floor widths. The cabin floor widths used in this assessment were 68.0 and 72.0 in. The aisleway width was 33.0 in. for the 68.0-in. floor width and 37.25 in. for the 72.0-in. floor width. Aisleway width is the usable space for the Soldiers to traverse the aisle, stow their gear, and position their legs and feet while seated. The bench seats were configured to replicate a side door configuration (similar to the UH-60 Black Hawk). The side door configuration allowed for

assessment of the seating configuration for 9 and 14 troops. Steps were used at the right and left cabin doors during the assessment to reduce the probability of Soldier injury during ingress and egress. The interior and exterior dimensions of the cabin are listed in appendix A.



Figure 1. JMR medium-variant cabin mockup.

### 1.3 Participants

Participants included 18 male infantry Soldiers assigned to the Experimental Force at Fort Benning, GA, of which 17 were enlisted (11B military occupation specialty [MOS]) with ranks ranging from PVT to SSG, and 1 was a commissioned officer (11A MOS) with a rank of CPT. The combat gear they wore was comparable to the Rifle Platoon Basic Load (82nd Airborne Division Operation Enduring Freedom XII, 72-h load). Examples of the combat gear they wore are listed in appendix B. The relevant demographic characteristics of the Soldiers are listed in table 1.

Table 1. Soldier demographics (N = 18).

Summary of Demographic Characteristics	Age (years)	Rank/Number of Each	Combat Gear Worn (Rifle Platoon Basic Load)
Mean Median Range	23 23 19–35	CPT (1) SSG (1) SGT (2) SPC (5) PFC (6) PV2 (1) PVT (2)	- Platoon leader/Medic - Platoon sergeant - Squad leader - Team leader - Medic - Rifleman (2) - M240 Gunner and assistant gunner - Antitank Javelin 60-mm gunner and 60-mm assistant gunner - M203 Grenadier - Low-level voice intercept radio telephone operator (2) - Forward observer (2)

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## 2. Method

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### 2.1 Anthropometric Measurements

The Soldiers were briefed about the purpose of the assessment and assigned to one of two measuring stations where ARL-HRED personnel obtained anthropometric measurements with the Soldiers attired in physical training clothes (figure 2). The same anthropometric measurements were taken with the Soldiers attired in their combat gear. The following anthropometric dimensions were measured:

- Weight
- Stature
- Sitting height
- Chest depth
- Hip breadth sitting
- Buttock-knee length
- Bideltoid breadth
- Forearm-to-forearm breadth
- Widest at waist (breadth of gear worn on the waist)



Figure 2. Anthropometric measurements.

The measurements were taken to determine the body size distribution of the Soldiers, identify the largest Soldiers, and document differences in Soldier bulk with and without combat gear. The body size distribution of the Soldiers (figure 3) was primarily dispersed across the medium and large range of anthropometric dimensions based on the anthropometric database of U.S. Army Soldiers.<sup>1</sup> The largest Soldiers were identified and seated together during the assessment to evaluate space restrictions for large males, and the largest male wore the Medic gear, which was the bulkiest ensemble. This allowed an assessment of space requirements for the largest male Soldier with the bulkiest gear. The largest male was at the 99th percentile rank for most anthropometric dimensions. The differences in bulk between Soldiers with and without combat gear will be used to refine the human-figure models for the JMR Configuration Trades and Analysis Study. The anthropometric measurement data are listed in appendix C. Figure 4 illustrates the body size distribution for each seat along with the combat gear they wore during

<sup>1</sup> Gordon, C.; Bradtmiller, B.; Churchill, T.; Clauser, C.; McConville, J.; Tebbetts, I.; Walker, R. 1988 *Anthropometry Survey of U.S. Army Personnel: Methods and Summary Statistics*; Technical Report Natick/TR-89/044; U.S. Army Natick Research, Development and Engineering Center: Natick, MA, 1989.



the assessment to help assess seat space widths. This distribution was based on the bideltoid breadth, forearm-to-forearm, and hip breadth sitting measurements for each Soldier. Figure 5 illustrates the body size distribution for each seat along with the combat gear they wore during the assessment of cabin ceiling heights. This distribution was based on the stature and sitting height measurements for each Soldier. There were several differences in the body size distribution used to assess seat space widths versus cabin ceiling heights because several Soldiers had wide upper-body dimensions and correspondingly short height dimensions.

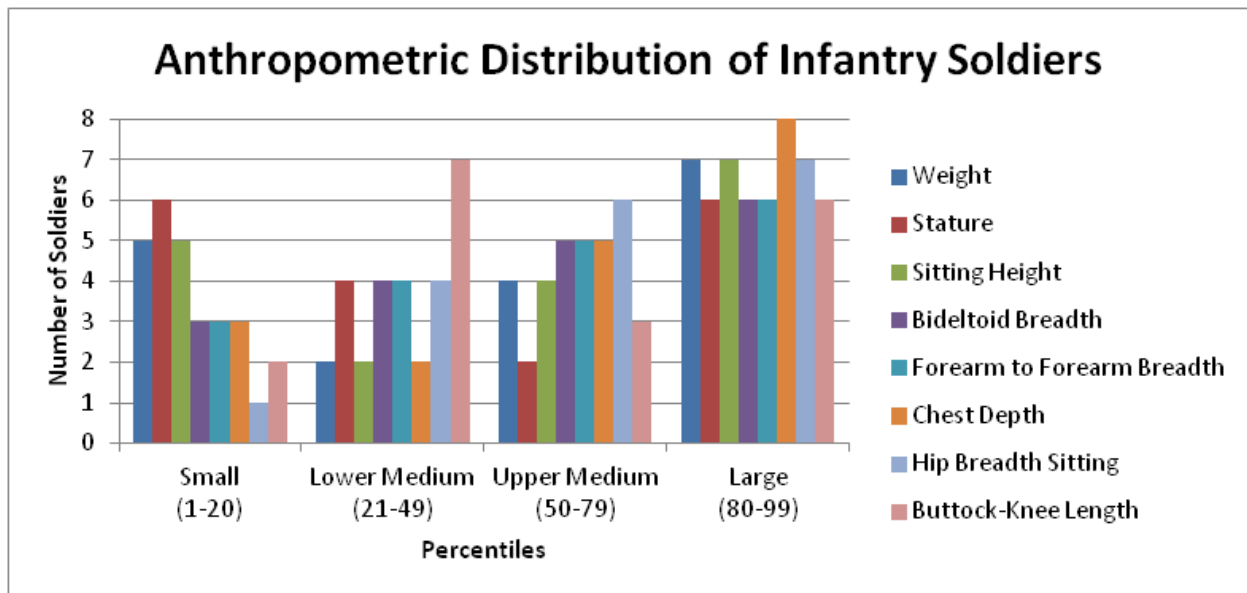


Figure 3. Anthropometric distribution.

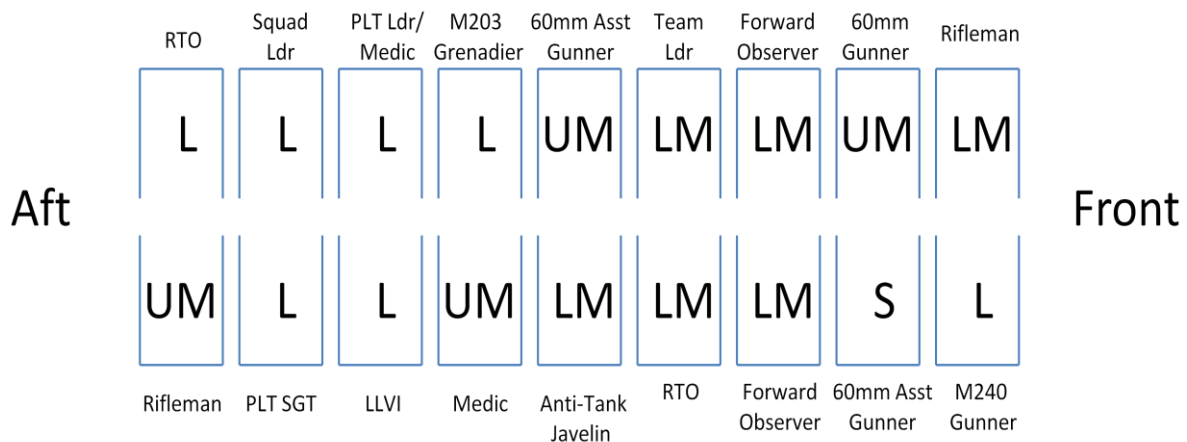


Figure 4. Soldier body size distribution to assess seat space widths: S = small, LM = lower medium, UM = upper medium, L = large, and LLVI = low level voice intercept.

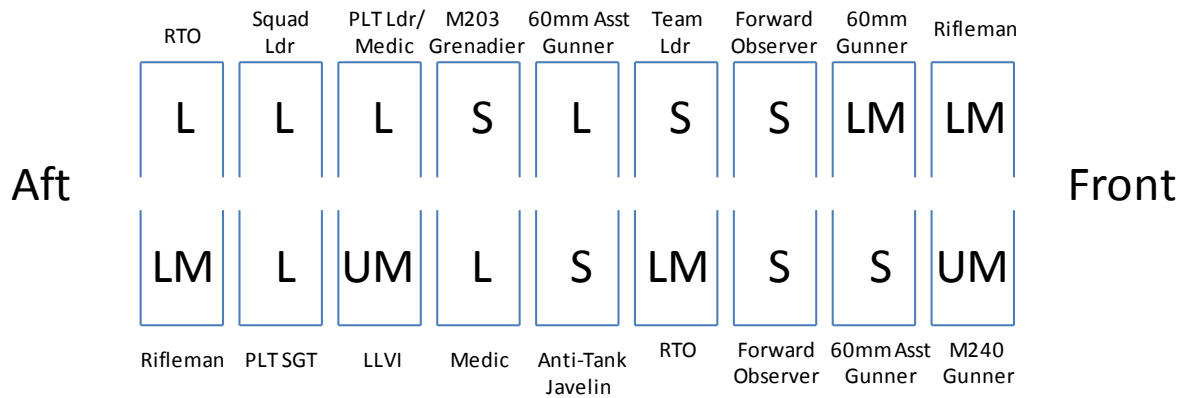


Figure 5. Soldier body size distribution to assess cabin ceiling heights: S = small, LM = lower medium, UM = upper medium, and L = large.

## 2.2 Assessment Procedure

The Soldiers were assigned a number 1–18 that was placed on their helmet. Corresponding numbers were also placed on the seat dividers in the mockup. The Soldiers sat next to their number on the seat dividers for all tasks performed during the assessment. This standardized placement of Soldiers during the assessment and reduced the variance associated with measurements and questionnaire responses. For example, a medium-sized male might have more seated space while sitting next to two small males when assessing a seat width of 22.0 in. than while sitting next to two large males while assessing a seat width of 24.0 in. Sitting next to the same personnel during the entire assessment helped ensure that the Soldiers provided consistent responses about differences in volume of space for the different seat width assessments. This also helped standardize physical measurements taken between the Soldiers (e.g., knee clearance) during the assessment.

The Soldiers received a short brief about the tasks required for assessing seat space widths, cabin ceiling heights, floor widths, ingress/egress, emergency egress in the mockup, and the need for deliberate and safe ingress/egress. They donned their combat gear and assembled at the left cabin door, right cabin door, or ramp depending on their assigned number. After a short countdown, they proceeded to ingress the mockup and sit next to their corresponding number on the seat dividers. They stowed their rucksacks and weapons at their feet in the aisle, which is what they typically do during flight in an aircraft of similar size. ARL-HRED and AFDD personnel then asked each Soldier questions about the volume of space they had for each seat width. The questions addressed whether the Soldier fit in the seat space, any restriction of body movement for torso pivot, lateral torso lean (left and right), arm movement, leg movement, positioning of feet, gear that had to be repositioned for seating, and any problems with stowage of gear. Measurements were taken while the Soldiers were seated in the mockup.

After a short countdown, the Soldiers proceeded to egress the mockup and took a short break. The mockup interior was reconfigured (e.g., seat width and cabin ceiling height) for the next trial and the process was repeated. All ingress and egress events were timed and videotaped by ARL-HRED, and individual pictures of the Soldiers were taken while they were seated in the mockup to aid in assessing space requirements.

### **2.3 Questionnaires**

The Soldier questionnaires were developed in accordance with published guidelines for proper format and content.<sup>2</sup> A brief review of the questionnaires was conducted by a sample of Soldiers to ensure the questions could be quickly and easily understood. The questionnaires were administered to the Soldiers and used to assess restrictions on their body posture and movement for torso pivot, lateral torso lean (left and right), arm movement, leg movement, positioning of feet while seated, and gear stowage restrictions; repositioning of gear to accommodate seating; posture, loss of balance and difficulty carrying gear during ingress and egress; and differences in difficulty for ingress and egress at floor widths of 68.0 versus 72.0 in.

### **2.4 Data Analysis**

Time data for ingress, egress, and emergency egress were analyzed with means, ranges, and standard deviations. Soldier responses to the questionnaires were analyzed with means and percentages.

### **2.5 Assessment Limitations**

Primary limitations included the small sample size of Soldiers ( $N = 18$ ) who participated in the assessment, the inability to assess fatigue and discomfort (while seated), and all potential combat load configurations being used (by U.S. Army units) due to the short duration of the assessment. This assessment only addressed space claim requirements for infantry Soldiers. Space claim requirements for other groups of Soldiers and their gear/equipment (e.g., flight medics) were not assessed. Future combat gear (e.g., exoskeletons) should be assessed when it becomes available. The information and data listed in the Results and Summary/Recommendations sections of this report need to be interpreted based on these limitations. Additional data should be collected during future assessments and modeling to augment and expand the findings contained in this report.

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<sup>2</sup> O'Brien, T. G.; Charlton, S. G. *Handbook of Human Factors Testing and Evaluation*; Lawrence Erlbaum Associates: Mahwah, NJ, 1996.

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### 3. Results

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#### 3.1 Seat Space Widths

The seat space assessment was conducted with both the cabin ceiling height and floor width set at 72.0 in. The seat widths were set at 20.0, 22.0 24.0, and 26.0 in. Table 2 summarizes the Soldier responses about how well they fit in the different seat space widths. Additional data is contained in appendix D. Tables 3–6 summarize the Soldier responses by body size for each seat space width. Figures 6–8 depict fit for a sample of the larger Soldiers in the different seat space widths; the figures appear in this section with the associated text.

Table 2. Seat space questionnaire responses.

<b>How Restrictive Was Body Movement for 20.0 in.?</b>	<b>Very Restrictive</b>	<b>Somewhat Restrictive</b>	<b>Not Restrictive</b>
Torso pivot	50%	39%	11%
Lateral torso lean (left and right)	44%	28%	28%
Arm movement (both arms)	39%	61%	0%
Leg movement (both legs)	44%	39%	17%
Positioning of feet	28%	33%	39%
<b>How Restrictive Was Body Movement for 22.0 in.?</b>	<b>Very Restrictive</b>	<b>Somewhat Restrictive</b>	<b>Not Restrictive</b>
Torso pivot	0%	22%	78%
Lateral torso lean (left and right)	0%	28%	72%
Arm movement (both arms)	22%	17%	61%
Leg movement (both legs)	17%	39%	44%
Positioning of feet	11%	22%	67%
<b>How Restrictive Was Body Movement for 24.0 in.?</b>	<b>Very Restrictive</b>	<b>Somewhat Restrictive</b>	<b>Not Restrictive</b>
Torso pivot	0%	0%	100%
Lateral torso lean (left and right)	0%	0%	100%
Arm movement (both arms)	0%	22%	78%
Leg movement (both legs)	0%	33%	67%
Positioning of feet	0%	28%	72%

Table 2. Seat space questionnaire responses (continued).

<b>How Restrictive Was Body Movement for 26.0 in.?</b>	<b>Very Restrictive</b>	<b>Somewhat Restrictive</b>	<b>Not Restrictive</b>
Torso pivot	0%	6%	94%
Lateral torso lean (left and right)	0%	11%	89%
Arm movement (both arms)	0%	0%	100%
Leg movement (both legs)	0%	6%	94%
Positioning of feet	0%	0%	100%

### 3.1.1 20.0-in. Seat Width

As shown in table 3, fit was very tight for the largest Soldiers in the 20.0-in. seat space. The majority of Soldiers (72%–100%) reported that their upper-body movement (torso and arms) was “very” or “somewhat” restricted. Eighty-three percent of Soldiers reported that their leg movement was “very restricted” (44%) or “somewhat” restricted (39%). Sixty-one percent of Soldiers reported that positioning of their feet was “very restricted” (28%) or “somewhat restricted” (33%). The larger Soldiers attempted to reposition their upper bodies to gain a comfortable posture but were not successful due to the limited seat space.

Table 3. Questionnaire responses by body size for 20.0-in. seat width.

Soldier Size	Torso Pivot			Torso Lean			Arm Movement		
	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive
Large	71%	29%	0%	71%	29%	0%	71%	29%	0%
Upper Medium	50%	25%	25%	75%	0%	25%	25%	75%	0%
Lower Medium	33%	50%	17%	0%	50%	50%	17%	83%	0%
Small	0%	100%	0%	0%	0%	100%	0%	100%	0%

Soldier Size	Leg Movement			Feet Positioning		
	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive
Large	71%	0%	29%	43%	29%	29%
Upper Medium	25%	50%	25%	25%	0%	75%
Lower Medium	33%	67%	0%	17%	67%	17%
Small	0%	100%	0%	0%	0%	100%

### **3.1.2 Large Soldiers**

The large Soldiers reported more upper- and lower-body movement restriction than the medium and smaller-size Soldiers. All large Soldiers (N = 7) reported that their upper-body movement was “very” (71%) or “somewhat” (29%) restricted. Seventy-one percent (N = 5) of the large Soldiers reported that leg movement was “very restricted,” and 29% (N = 2) reported that leg movement was “not restricted.” Seventy-one percent reported that positioning of their feet was “very restricted” (43%) or “somewhat restricted” (29%).

### **3.1.3 Upper-Medium-Size Soldiers**

Of the upper-medium-size Soldiers, 75%–100% (N = 3–4) reported that their upper-body movement was “very” or “somewhat” restricted. Seventy-five percent reported that torso pivot was “very restricted” (50%) or “somewhat restricted” (25%), torso lean was “very restricted” (75%), and arm movement was “very restricted” (25%) or “somewhat restricted” (75%). Seventy-five percent reported that leg movement was “very restricted” (25%) or “somewhat restricted” (50%). One Soldier reported that positioning of his feet was “very restricted” while three Soldiers reported that positioning of their feet was “not restricted.”

### **3.1.4 Lower-Medium-Size Soldiers**

Of lower-medium-size Soldiers, 50%–100% (N = 3–6) reported that their upper-body movement was “very” or “somewhat” restricted. Eighty-three percent (N = 5) reported that torso pivot was “very restricted” (33%) or “somewhat restricted” (50%), torso lean was “somewhat restricted” (50%), and arm movement was “very restricted” (17%) or “somewhat restricted” (83%). Thirty-three percent reported that leg movement was “very restricted” or “somewhat restricted” (67%). Seventeen percent reported that positioning of their feet was “very restricted” or “somewhat restricted” (67%).

### **3.1.5 Small Soldier**

The small Soldier reported that his torso pivot and arm movement was “somewhat restricted.” He reported that his torso lean was not restricted. He reported that his leg movement was “somewhat restricted” and positioning of his feet was “not restricted.”

### **3.1.6 Soldier Comments**

Nine Soldiers provided comments about their body movement restriction to include not being able to put their arms or torso against the back of the seat (lower-medium body size/antitank Javelin, upper-medium body size/60-mm gunner, small body size/60-mm assistant gunner), no upper-body lateral movement (lower-medium body size/radio-telephone operator, lower-medium body size/forward observer), and restricted leg and foot movement (lower-medium body size/radio-telephone operator, lower-medium body size/forward observer). One Soldier (small body size/60-mm assistant gunner) reported that his canteen had to be repositioned before he was

able to fit in the seat space, and another Soldier (lower-medium body size/rifleman) reported that he had to reposition the ammunition pouch on his left side prior to being seated. It was observed that the shoulders and upper arms of several of the larger Soldiers overlapped the shoulder(s) of the Soldiers seated next to them when sitting erect with their back parallel to their seat. It was also observed that the majority of Soldiers had to maintain a confined and static seating position and did not have adequate space to reposition their upper torso, arms, legs, and feet to minimize muscle tension and fatigue. The limited space for the large Soldiers would make it difficult for them to use a restraint harness, and the large Soldiers would have very limited room to perform tasks such as using portable computing devices.

### 3.1.7 22.0-in. Seat Width

As shown in table 4, the Soldiers reported less restriction of upper-body, arm, and foot positioning for the 22.0 in. seat space (versus 20-in. seat space) with (about) half of the Soldiers reporting that leg movement was restricted. The majority of Soldiers (61%–78%) reported that their upper-body movement was not restricted. Fifty-six percent of Soldiers reported that their leg movement was “somewhat” restricted and 33% reported that positioning of their feet was “very” or “somewhat” restricted. Three Soldiers commented that space was tight on the left and right side of their upper body. Four Soldiers reported that their rucksack had to be repositioned before being seated. The majority of Soldiers had somewhat adequate space to reposition their upper torso and arms to minimize muscle tension and fatigue. Most Soldiers had limited space to laterally reposition their legs and feet to minimize muscle tension and fatigue.

Table 4. Questionnaire responses by body size for 22.0-in. seat width.

Soldier Size	Torso Pivot			Torso Lean			Arm Movement		
	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive
Large	0%	43%	57%	0%	57%	43%	43%	14%	43%
Upper Medium	0%	25%	75%	0%	25%	75%	25%	25%	50%
Lower Medium	0%	0%	100%	0%	0%	100%	0%	17%	83%
Small	0%	0%	100%	0%	0%	100%	0%	0%	100%

Soldier Size	Leg Movement			Feet Positioning		
	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive
Large	43%	29%	29%	29%	29%	43%
Upper Medium	0%	75%	25%	0%	50%	50%
Lower Medium	0%	33%	67%	0%	0%	100%
Small	0%	0%	100%	0%	0%	100%

### **3.1.8 Large Soldiers**

The large Soldiers reported more upper and lower-body movement restriction than the medium- and smaller-size Soldiers. Forty-three percent (N = 3) reported that torso pivot was “somewhat restricted” and 57% (N = 4) reported that torso lean was “somewhat restricted.” For arm movement, 43% reported that it was “very restricted” while 14% reported that it was “somewhat restricted.” Seventy-two percent (N = 5) of the large Soldiers reported that leg movement was “very restricted” (43%) or “somewhat restricted” (29%). Fifty-seven percent reported that positioning of their feet was “very restricted” (28%) or “somewhat restricted” (29%).

### **3.1.9 Upper-Medium-Size Soldiers**

Of upper-medium-size Soldiers, 25%–50% (N = 1–2) reported that their upper-body movement was “very” or “somewhat” restricted. One Soldier reported that torso pivot was “somewhat restricted” (25%), torso lean was “somewhat restricted” (25%), and arm movement was “very restricted” (25%) or “somewhat restricted” (25%). Seventy-five percent reported (N = 3) that leg movement was “somewhat restricted.” Fifty percent reported that positioning of their feet was “somewhat restricted.”

### **3.1.10 Lower-Medium-Size Soldiers**

Only one lower-medium-size Soldier reported that his upper-body movement was restricted. He reported that arm movement was “somewhat restricted,” while the rest of the Soldiers reported that it was “not restricted.” All Soldiers reported that torso pivot and torso lean were “not restricted.” Thirty-three percent reported that leg movement was “somewhat restricted.” All Soldiers reported that positioning of their feet was “not restricted.”

### **3.1.11 Small Soldier**

The small Soldier reported that his upper and lower-body movement was “not restricted.”

### **3.1.12 24.0-in. Seat Width**

As shown in table 5, the majority of Soldiers (78%–100%) reported that their upper-body movement was not restricted, and 67%–72% reported that leg movement and foot positioning was “not restricted.” No comments were provided about problems with upper- or lower-body movement restriction. Four Soldiers commented that their rucksacks had to be repositioned before being seated and one Soldier reported that his medic bag had to be repositioned prior to being seated. The majority of Soldiers had adequate space to reposition their upper torso and arms to minimize muscle tension and fatigue. Space to laterally reposition legs and feet was improved compared with the 20.0- and 22.0-in. seat spaces.



Table 5. Questionnaire responses by body size for 24.0-in. seat width.

Soldier Size	Torso Pivot			Torso Lean			Arm Movement		
	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive
Large	0%	0%	100%	0%	0%	100%	0%	29%	71%
Upper Medium	0%	0%	100%	0%	0%	100%	0%	50%	50%
Lower Medium	0%	0%	100%	0%	0%	100%	0%	0%	100%
Small	0%	0%	100%	0%	0%	100%	0%	0%	100%

Soldier Size	Leg Movement			Feet Positioning		
	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive
Large	0%	71%	29%	0%	71%	29%
Upper Medium	0%	25%	75%	0%	0%	100%
Lower Medium	0%	0%	100%	0%	0%	100%
Small	0%	0%	100%	0%	0%	100%

### 3.1.13 Large Soldiers

All large Soldiers (N = 7) reported that torso pivot and torso lean were “not restricted.” Two Soldiers reported that arm movement was “somewhat restricted.” Seventy-one percent (N = 5) reported that leg movement and positioning of their feet was “somewhat restricted.”

### 3.1.14 Upper-Medium-Size Soldiers

All upper-medium Soldiers (N = 4) reported that torso pivot and torso lean were “not restricted.” Fifty-percent reported that arm movement was “somewhat restricted.” Twenty-five percent reported that leg movement was “somewhat restricted.” All Soldiers reported that positioning of their feet was “not restricted.”

### 3.1.15 Lower-Medium-Size Soldiers

All lower-medium Soldiers (N = 6) reported that their upper- and lower-body movement was “not restricted.”

### 3.1.16 Small Soldier

The small Soldier reported that his upper- and lower-body movement was “not restricted.”

### 3.1.17 26.0-in. Seat Width

As shown in table 6, the majority of Soldiers (89%–100%) reported that their upper-body movement was “not restricted.” All Soldiers reported that positioning of feet was “not restricted.” Only 6% of Soldiers reported that leg movement was “restricted.” No comments were provided about body movement restriction or gear that had to be repositioned prior to being seated. All Soldiers had adequate space to reposition their upper torso and arms to minimize muscle tension and fatigue. Space to laterally reposition legs and feet was improved compared with the 20.0-, 22.0-, and 24.0-in. seat spaces.

Table 6. Questionnaire responses by body size for 26.0-in. seat width.

Soldier Size	Torso Pivot			Torso Lean			Arm Movement		
	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive
Large	0%	0%	100%	0%	14%	86%	0%	0%	100%
Upper Medium	0%	0%	100%	0%	0%	100%	0%	0%	100%
Lower Medium	0%	17%	83%	0%	17%	83%	0%	0%	100%
Small	0%	0%	100%	0%	0%	100%	0%	0%	100%

	Leg Movement			Feet Positioning		
	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive
Large	0%	0%	100%	0%	0%	100%
Upper Medium	0%	0%	100%	0%	0%	100%
Lower Medium	0%	17%	83%	0%	0%	100%
Small	0%	0%	100%	0%	0%	100%

The seat space assessment was conducted with the benches set at a floor width of 72.0 in. Soldiers would have likely reported more lower-body movement restriction if the benches were set at a floor width of 68.0 in.

### 3.1.18 Large Soldiers

All large Soldiers (N = 7) reported that torso pivot and arm movement were “not restricted.” One Soldier reported that torso lean was “somewhat restricted.” All Soldiers reported that leg movement and positioning of their feet was “not restricted.”

### 3.1.19 Upper-Medium-Size Soldiers

All upper-medium Soldiers (N = 4) reported that their upper and lower-body movement was “not restricted.”

### 3.1.20 Lower-Medium-Size Soldiers

All lower-medium Soldiers (N = 6) reported that arm movement was “not restricted.” Eighty-three percent (N = 5) reported that torso pivot and torso lean were “not restricted.” One Soldier reported that torso pivot and torso lean were “somewhat restricted.” All Soldiers reported that positioning of their feet was “not restricted.” Eighty-three percent reported that leg movement was “not restricted.” One Soldier reported that his leg movement was “somewhat restricted.”

### 3.1.21 Small Soldier

The small Soldier reported that his upper and lower-body movement was “not restricted.”

### 3.1.22 23.0-in. Seat Width

An assessment of the 23.0-in. seat space width was conducted with the three largest Soldiers (figure 6). The largest male Soldier wore ammunition pouches on his lower left and right torso to assess whether he could fit in the seat space as well as any restriction it would place on upper-body movement for him and the other large Soldiers. The three large Soldiers fit in the seat space with moderate restriction to their upper-body movement. The largest Soldier was measured at the 99th percentile for bideltoid breadth and hip breadth, sitting. If he were representative of the 95th percentile male for these measurements, the three Soldiers would have had less upper-body restriction at the 23.0-in. seat space width. The three Soldiers commented that the 23.0-in. seat spacing would be the minimally acceptable seat space width if they were seated next to other large Soldiers.

Figures 6–8 depict fit for a sample of the larger Soldiers in the different seat space widths.

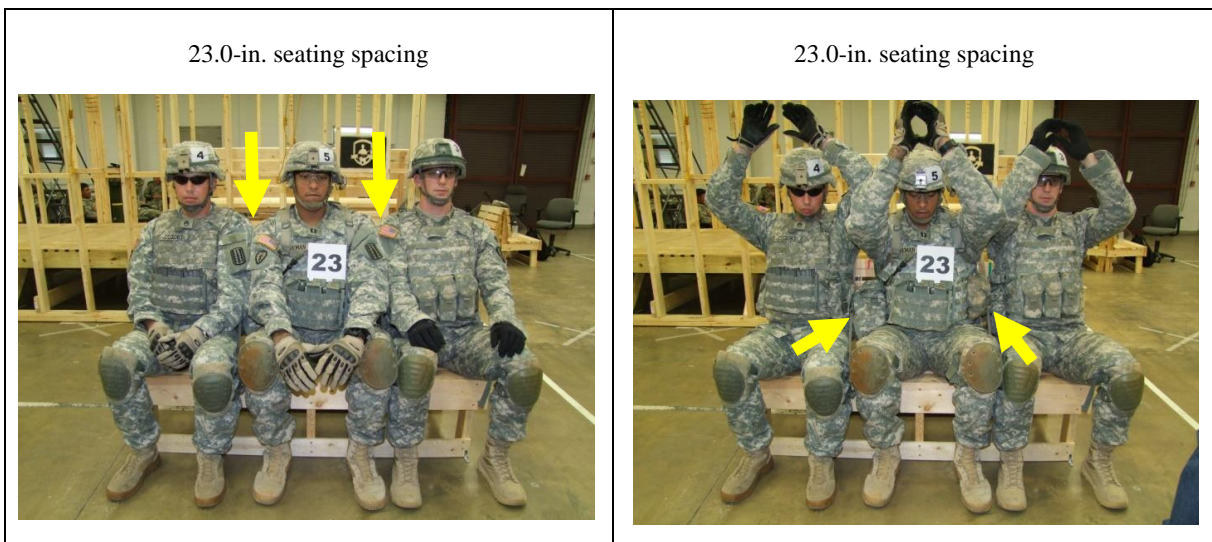


Figure 6. 23.0-in. seat spacing for larger soldiers.

20.0-in. seat spacing



22.0-in. seat spacing



24.0-in. seat spacing



26.0-in. seat spacing



Figure 7. Examples of seat spacing for larger soldiers.



Figure 8. 24.0-in. seat spacing for large soldier wearing medic gear and two M249 ammo pouches.

### **3.1.23 Seat Space Accommodation for 95th Percentile Infantry Soldier (Bideloid Breadth and Waist Breadth) With Medic Gear**

Aviation requirements documents typically specify that the 95th percentile male should be accommodated by aircraft design. Figure 9 identifies how well the 95th percentile male Soldier would be accommodated with the seat space sizes used during this assessment. The graph was generated using the anthropometric measurements obtained from the largest male Soldier (wearing medic gear) and resized to 95th percentile male body dimensions for bideltoid breadth and waist breadth (including the gear worn around the waist). Consequently, 1.0 in. was added (0.5 in. on each side) to the measurements to provide space for limited range of movement and the ability to reposition his upper torso, arms, legs, and feet to minimize fatigue. Based on these measurements, the 95th percentile Soldier would need a minimum seat spacing of 23.16 in. to accommodate gear worn around the waist (e.g., medic and ammo pouches) and 23.35 in. to accommodate bideltoid breadth. Because it is not likely that the 95th percentile male would often have other 95th percentile males sitting on both sides of him, a minimum seat width of 23.0 in. would provide adequate space in instances when smaller Soldiers (e.g., 75th percentile) are seated next to him.



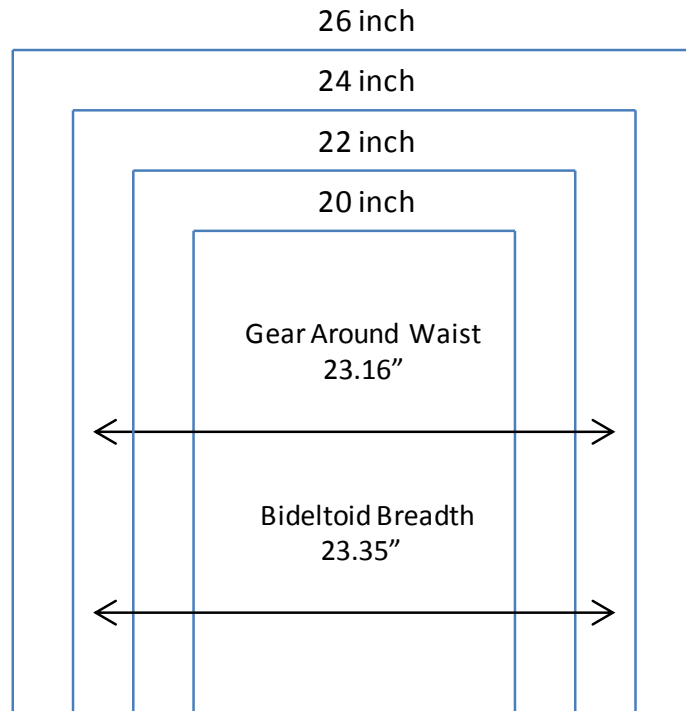


Figure 9. Seat space accommodation for 95th percentile infantry soldier (bideloid breadth and waist breadth) with medic gear.

### 3.2 Cabin Ceiling Heights

All Soldiers were able to ingress and egress the mockup cabin at ceiling heights of 54.0, 60.0, 66.0, and 72.0 in. Ingress and egress times were progressively faster as the cabin ceiling heights were raised to a higher position. Table 7 summarizes the Soldiers' responses about posture, stabilization, difficulty carrying gear, and elapsed time to ingress at the different ceiling heights.

Table 7. Cabin ceiling height questionnaire responses.

<b>Cabin Ceiling Height = 54.0 in.</b> <b>Average ingress time = 23.5 s / Average egress time = 21.3 s</b>			
Top of helmet touching cabin ceiling when seated?	Yes = 0%, No = 100%		
	Constantly	Often	Never
How often did you have to bend torso and/or knees while ingressing?	100%	0%	0%
How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress?	17%	11%	72%
—	Very difficult	Somewhat difficult	Not difficult
How difficult was it to carry and maneuver your gear during ingress due to ceiling height?	39%	50%	11%
<b>Cabin Ceiling Height = 60.0 in.</b> <b>Average ingress time = 18.3 s / Average egress time = 16.8 s</b>			
Top of helmet touching cabin ceiling when seated?	Yes = 0%, No = 100%		
	Constantly	Often	Never
How often did you have to bend torso and/or knees while ingressing?	94%	6%	0%
How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress?	17%	0%	83%
—	Very difficult	Somewhat difficult	Not difficult
How difficult was it to carry and maneuver your gear during ingress due to ceiling height?	28%	39%	33%
<b>Cabin Ceiling Height = 66.0 in.</b> <b>Average ingress time = 16.5 s / Average egress time = 15.8 s</b>			
Top of helmet touching cabin ceiling when seated?	Yes = 0%, No = 100%		
	Constantly	Often	Never
How often did you have to bend torso and/or knees while ingressing?	11%	67%	22%
How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress?	0%	11%	89%
—	Very difficult	Somewhat difficult	Not difficult
How difficult was it to carry and maneuver your gear during ingress due to ceiling height?	6%	33%	61%
<b>Cabin Ceiling Height = 72.0 in.</b> <b>Average ingress time = 16.3 s / Average egress time = 14.0 s</b>			
Top of helmet touching cabin ceiling when seated?	Yes = 0%, No = 100%		
	Constantly	Often	Never
How often did you have to bend torso and/or knees while ingressing?	6%	6%	88%
How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress?	0%	0%	100%
—	Very Difficult	Somewhat Difficult	Not Difficult
How difficult was it to carry and maneuver your gear during ingress due to ceiling height?	0%	0%	100%

Figure 10 illustrates the body size distribution for each seat along with the combat gear they wore during the assessment. The body size classification (small, lower-medium, upper-medium, and large) was based on the stature measurement for each Soldier.

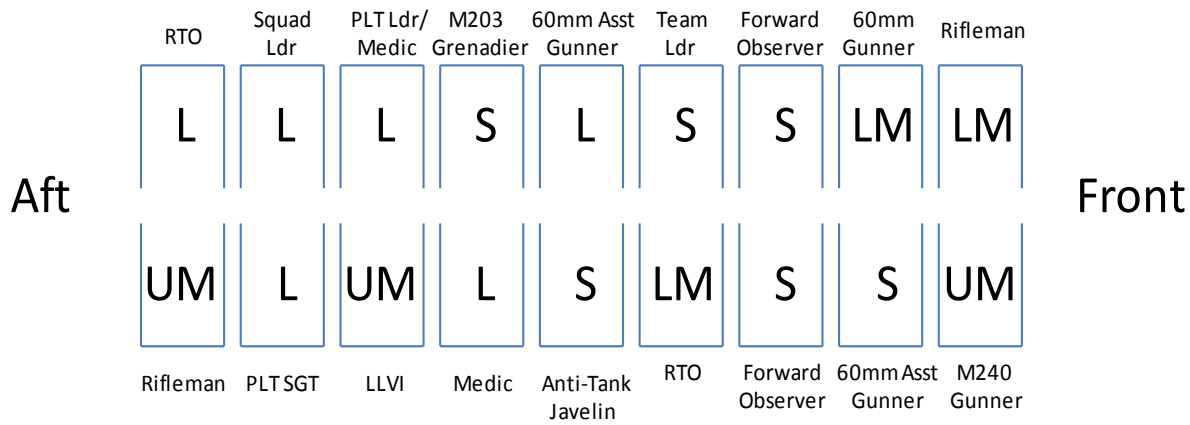


Figure 10. Body-size distribution for cabin ceiling height assessment; S = small, LM = lower medium, UM = upper medium, and L = large.

### 3.2.1 54.0-in. Ceiling Height

Tables 8–11 summarize the Soldier responses by body size for each cabin ceiling height and appear with the associated text in the following paragraphs. As shown in table 8, all Soldiers reported that they had to constantly bend their torso and knees and adopt a stooped posture during ingress and egress. The larger Soldiers had to adopt a very stooped posture to ingress (and egress) the cabin. The stooped posture combined with most Soldiers being top-heavy (because of the weight of their gear on their torso) increases the probability that they would lose their balance and fall during egress. The posture also increases the probability of lower back strain. The weight of the combat gear that the Soldiers wore during the assessment ranged from 57 to 99 lb. One Soldier tripped and fell (in the aisle) during egress. The night-vision goggle (NVG) mount on the helmet of one Soldier struck the cabin ceiling, which caused his head to be jerked back during egress. The majority of the Soldiers inadvertently pushed their helmets and/or upper backs through the cabin ceiling netting during ingress and egress due to the very limited vertical space between the ceiling and the cabin floor. Four Soldiers inadvertently pushed their gear (e.g., rifle, Javelin, packs) through the cabin ceiling netting when moving the gear to the floor as they settled into their seats. Twenty-eight percent of the Soldiers reported that they had to “constantly” (17%) or “often” (11%) place their hands on other Soldiers or the cabin interior to maintain balance during ingress. Eighty-nine percent reported that it was “very difficult” (39%) or “somewhat difficult” (50%) to carry and maneuver their gear during ingress due to the ceiling height. None of the Soldiers’ helmets touched the bottom of the cabin ceiling while seated. The



helmets of the largest Soldiers (when sitting erect) were within approximately 1.0–2.0 in. of the bottom of the cabin ceiling. It took the Soldiers 23.5 s to ingress the cabin and be seated and 21.3 s to egress the cabin.

Table 8. Questionnaire responses by body size for 54.0-in. ceiling height.

Soldier Size	Top of helmet touching cabin ceiling when seated?		How often did you have to bend torso and/or knees while ingressing			How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress			How difficult was it to carry and maneuver your gear during ingress due to ceiling height?		
	Yes	No	Constantly	Often	Never	Constantly	Often	Never	Very Difficult	Somewhat Difficult	Not Difficult
Large	0%	100%	100%	0%	0%	50%	0%	50%	83%	17%	0%
Upper Medium	0%	100%	100%	0%	0%	0%	0%	100%	50%	50%	0%
Lower Medium	0%	100%	100%	0%	0%	0%	25%	75%	25%	75%	0%
Small	0%	100%	100%	0%	0%	0%	17%	83%	0%	67%	33%

### 3.2.2 Large Soldiers

All large Soldiers (N = 6) reported that they had to “constantly” bend their torso and/or knees during ingress. Fifty percent (N = 3) of the large Soldiers reported that they had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress while 50% reported that they “never” had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. Eighty-three percent (N = 5) reported that it was “very difficult” to carry and maneuver their gear during ingress due to ceiling height.

### 3.2.3 Upper-Medium-Size Soldiers

All upper-medium-size Soldiers (N = 2) reported that they had to “constantly” bend their torsos and/or knees during ingress. Both Soldiers reported that they did not have to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. One Soldier reported that it was “very difficult” to carry and maneuver their gear during ingress due to ceiling height while the other Soldier reported that it was “somewhat difficult.”

### 3.2.4 Lower-Medium-Size Soldiers

All lower-medium-size Soldiers (N = 4) reported that they had to “constantly” bend their torso and/or knees during ingress. One Soldier reported that he had to “often” place his hands on other Soldiers or cabin interior to maintain balance during ingress while the other three Soldiers reported that they “never” had to place their hands on other Soldiers or cabin interior to maintain

balance during ingress. One medium-size Soldier reported that it was “very difficult” to carry and maneuver his gear during ingress due to ceiling height while the other three Soldiers reported that it was “somewhat difficult.”

### 3.2.5 Small Soldiers

All small Soldiers (N = 6) reported that they had to “constantly” bend their torso and/or knees during ingress. One reported that he had to place his hands on other Soldiers or cabin interior to maintain balance during ingress while the other five Soldiers reported that they “never” had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. Sixty-seven percent reported that it was “somewhat difficult” to carry and maneuver their gear during ingress due to ceiling height while 33% reported that it was “not difficult.”

### 3.2.6 60.0-in. Ceiling Height

As shown in table 9, all Soldiers reported that they had to “constantly” (94%) or “often” (6%) bend their torso and knees and adopt a stooped posture during ingress and egress. The stooped posture combined with most Soldiers being top-heavy (because of the weight of their gear on their torso) increases the probability that they would lose their balance and fall during egress out of the aircraft. The stooped posture also increases the probability of lower back strain. The larger Soldiers inadvertently pushed their helmet and/or upper back through the cabin ceiling netting during ingress and egress due to the limited vertical space between the ceiling and the cabin floor. Seventeen percent of the Soldiers reported that they had to “constantly” place their hands on other Soldiers or the cabin interior to maintain balance during ingress. Sixty-seven percent reported that it was “very difficult” (28%) or “somewhat difficult” (39%) to carry and maneuver their gear during ingress due to the ceiling height. None of the Soldiers’ helmets touched the bottom of the cabin ceiling while seated. It took the Soldiers 18.3 s to ingress the cabin and be seated and 16.8 s to egress the cabin.

Table 9. Questionnaire responses by body size for 60.0-in. ceiling height.

Soldier Size	Top of helmet touching cabin ceiling when seated?		How often did you have to bend torso and/or knees while ingressing			How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress			How difficult was it to carry and maneuver your gear during ingress due to ceiling height?		
	Yes	No	Constantly	Often	Never	Constantly	Often	Never	Very Difficult	Somewhat Difficult	Not Difficult
Large	0%	100%	100%	0%	0%	50%	0%	50%	50%	50%	0%
Upper Medium	0%	100%	100%	0%	0%	0%	0%	100%	50%	50%	0%
Lower Medium	0%	100%	100%	0%	0%	0%	0%	100%	25%	25%	50%
Small	0%	100%	83%	17%	0%	0%	0%	100%	0%	33%	67%

### **3.2.7 Large Soldiers**

All large Soldiers (N = 6) reported that they had to “constantly” bend their torso and/or knees during ingress. Fifty percent (N = 3) of the large Soldiers reported that they “constantly” had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress while 50% reported that they “never” had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. Fifty percent reported that it was “very difficult” to carry and maneuver their gear during ingress due to ceiling height while 50% reported that it was “somewhat difficult.”

### **3.2.8 Upper-Medium-Size Soldiers**

Both upper-medium-size Soldiers reported that they had to “constantly” bend their torsos and/or knees during ingress. None of the Soldiers reported that they had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. One Soldier reported that it was “very difficult” to carry and maneuver his gear during ingress due to ceiling height, while the other Soldier reported that it was “somewhat difficult.”

### **3.2.9 Lower-Medium-Size Soldiers**

All lower-medium-size Soldiers (N = 4) reported that they had to “constantly” bend their torsos and/or knees during ingress. None of the Soldiers reported that they had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. One Soldier reported that it was “very difficult” to carry and maneuver his gear during ingress due to ceiling height, one Soldier reported that it was “somewhat difficult” while two Soldiers reported that it was “not difficult.”

### **3.2.10 Small Soldiers**

Of the small Soldiers, 83% (N = 5) reported that they had to “constantly” bend their torsos and/or knees during ingress while one Soldier reported that he “often” had to bend his torso and/or knees during ingress. None of the Soldiers reported that they had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. Thirty-three percent (N = 2) reported that it was “somewhat difficult” to carry and maneuver their gear during ingress due to ceiling height while 67% (N = 4) reported that it was “not difficult.”

### **3.2.11 66.0-in. Ceiling Height**

As shown in table 10, 78% percent (N=14) of the Soldiers reported that they had to “constantly” (11%) or “often” (67%) bend their torsos and knees during ingress. The larger Soldiers typically had to adopt a slightly stooped posture during ingress and egress. A few Soldiers inadvertently pushed their helmets and/or upper backs through the cabin ceiling netting during ingress and egress due to the limited vertical space between the ceiling and the cabin floor. Eleven percent of the Soldiers reported that they had to “often” place their hands on other Soldiers or the cabin

interior to maintain balance during ingress. Thirty-nine percent reported that it was “very difficult” (6%) or “somewhat difficult” (33%) to carry and maneuver their gear during ingress due to the ceiling height. None of the Soldiers helmets touched the bottom of the cabin ceiling while seated. It took the Soldiers 16.5 s to ingress the cabin and be seated and 15.8 s to egress the cabin.

Table 10. Questionnaire responses by body size for 66.0-in. ceiling height.

Soldier Size	Top of helmet touching cabin ceiling when seated?		How often did you have to bend torso and/or knees while ingressing			How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress			How difficult was it to carry and maneuver your gear during ingress due to ceiling height?		
	Yes	No	Constantly	Often	Never	Constantly	Often	Never	Very Difficult	Somewhat Difficult	Not Difficult
Large	0%	100%	17%	83%	0%	0%	33%	67%	17%	50%	33%
Upper Medium	0%	100%	50%	50%	0%	0%	0%	100%	0%	100%	0%
Lower Medium	0%	100%	0%	75%	25%	0%	0%	100%	0%	25%	75%
Small	0%	100%	0%	50%	50%	0%	0%	100%	0%	0%	100%

### 3.2.12 Large Soldiers

Of the large Soldiers, 83% (N = 5) reported that they had to “often” bend their torsos and/or knees during ingress. One large Soldier reported that he “constantly” had to bend his torso and/or knees during ingress. Thirty-three percent of Soldiers reported that they “often” had to place their hands on other Soldiers or cabin interior to maintain balance during ingress while 67% reported that they “never” had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. One Soldier reported that it was “very difficult” to carry and maneuver his gear during ingress due to ceiling height, three Soldiers reported that it was “somewhat difficult,” and two Soldiers reported that it was “not difficult.”

### 3.2.13 Upper-Medium-Size Soldiers

One Soldier reported that he had to “constantly” bend his torso and/or knees during ingress while the other Soldier reported that he “often” had to bend his torso and/or knees. None of the Soldiers reported that they had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. Both Soldiers reported that it was “somewhat difficult” to carry and maneuver their gear during ingress due to ceiling height.

### 3.2.14 Lower-Medium-Size Soldiers

Three lower-medium-size Soldiers reported that they had to “often” bend their torsos and/or knees during ingress while one Soldier reported that he “never” had to bend his torso and/or knees. None of the Soldiers reported that they had to place their hands on other Soldiers or the

cabin interior to maintain balance during ingress. One Soldier reported that it was “somewhat difficult” to carry and maneuver his gear during ingress due to ceiling height while the other three Soldiers reported it was “not difficult.”

### 3.2.15 Small Soldiers

Of the small size Soldiers, 50% (N = 3) reported that they had to “often” bend their torsos and/or knees during ingress while 50% reported that they “never” had to bend their torsos and/or knees. None of the Soldiers reported that they had to place their hands on other Soldiers or cabin interior to maintain balance during ingress. All Soldiers reported that it was “not difficult” to carry and maneuver their gear during ingress due to ceiling height.

### 3.2.16 72.0-in. Ceiling Height

As shown in table 11, 88% (N = 16) of the Soldiers reported that they “never” had to bend their torsos and knees. One Soldier reported that he had to “constantly” bend his torso and knees during ingress, and one Soldier reported that he had to “often” bend his torso and knees during ingress. None of the Soldiers reported that they had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. All Soldiers reported that they had no difficulty carrying and maneuvering their gear during ingress due to the ceiling height. None of the Soldiers’ helmets touched the bottom of the cabin ceiling while seated. It took the Soldiers 16.3 s to ingress the cabin and be seated and 14.0 s to egress the cabin.

Table 11. Questionnaire responses by body size for 72.0-in. ceiling height.

Soldier Size	Top of helmet touching cabin ceiling when seated?		How often did you have to bend torso and/or knees while ingressing			How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress			How difficult was it to carry and maneuver your gear during ingress due to ceiling height?		
	Yes	No	Constantly	Often	Never	Constantly	Often	Never	Very Difficult	Somewhat Difficult	Not Difficult
Large	0%	100%	17%	17%	67%	0%	0%	100%	0%	0%	100%
Upper Medium	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%
Lower Medium	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%
Small	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%

### 3.2.17 Large Soldiers

One Soldier reported that he had to “constantly” bend his torso and/or knees during ingress and one Soldier reported that he had to “often” bend his torso and/or knees during ingress. The rest of the large Soldiers (N = 4) reported that they did not have to bend their torsos and/or knees during

ingress. All Soldiers reported that they “never” had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. All Soldiers reported that it was “not difficult” to carry and maneuver their gear during ingress because of ceiling height.

### **3.2.18 Upper-Medium-Size Soldiers**

All upper-medium-size Soldiers reported that they did not have to bend their torsos and/or knees during ingress. All Soldiers reported that they “never” had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. All Soldiers reported that it was “not difficult” to carry and maneuver their gear during ingress because of ceiling height.

### **3.2.19 Lower-Medium-Size Soldiers**

All lower-medium-size Soldiers reported that they did not have to bend their torsos and/or knees during ingress. All Soldiers reported that they “never” had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. All Soldiers reported that it was “not difficult” to carry and maneuver their gear during ingress due to ceiling height.

### **3.2.20 Small Soldiers**

All small Soldiers reported that they did not have to bend their torsos and/or knees during ingress. All Soldiers reported that they “never” had to place their hands on other Soldiers or the cabin interior to maintain balance during ingress. All Soldiers reported that it was “not difficult” to carry and maneuver their gear during ingress due to ceiling height.

Figure 11 shows the helmet clearance for the Soldiers (while seated) at the 54.0-in. cabin ceiling height. Figure 12 illustrates posture for a sample of Soldiers for the different ceiling heights during ingress and egress.



Figure 11. Helmet clearance for 54.0-in. cabin ceiling height.



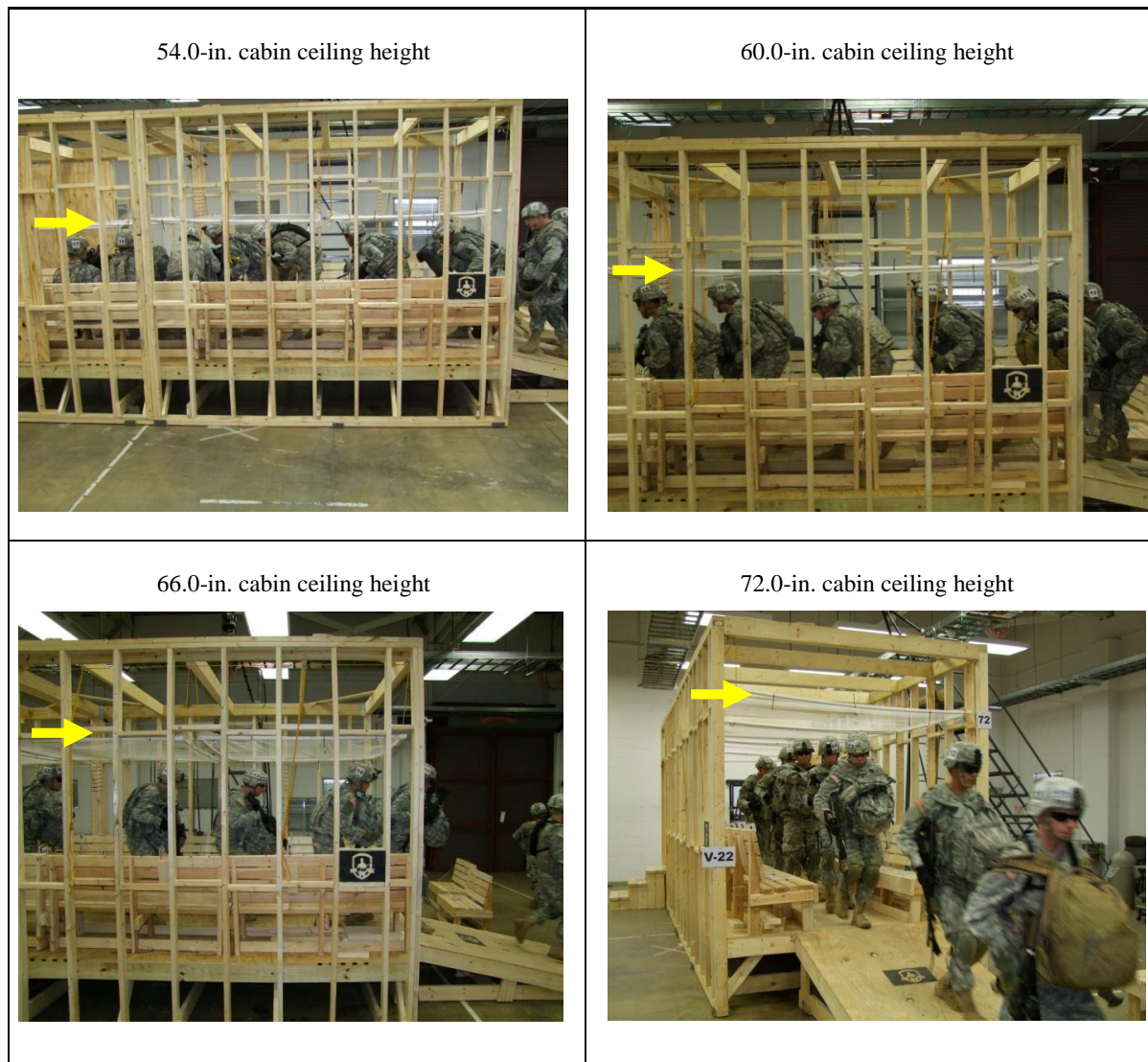


Figure 12. Ingress and egress for cabin ceiling heights.

Figure 13 depicts how far the 95th percentile male would have to bend over during ingress and egress at the ceiling heights that were evaluated during the assessment. At the 54.0- and 60.0-in. heights, the 95th percentile male would have to significantly bend his knees and adopt a very stooped upper-body posture. At the 66.0-in. height, he would have to flex his knees and adopt a moderately stooped upper-torso posture. At 72.0 in., he would only need to slightly bend his knees and bow his head. The dimensions in figure 13 are based on a 95th percentile male height of 73.48 in. with 1.0 in. added for boots and 1.5 in. added for the helmet. Figure 14 provides the same comparison of approximately how far the largest Soldier (used during the assessment) would have to bend over during ingress and egress at the ceiling heights.

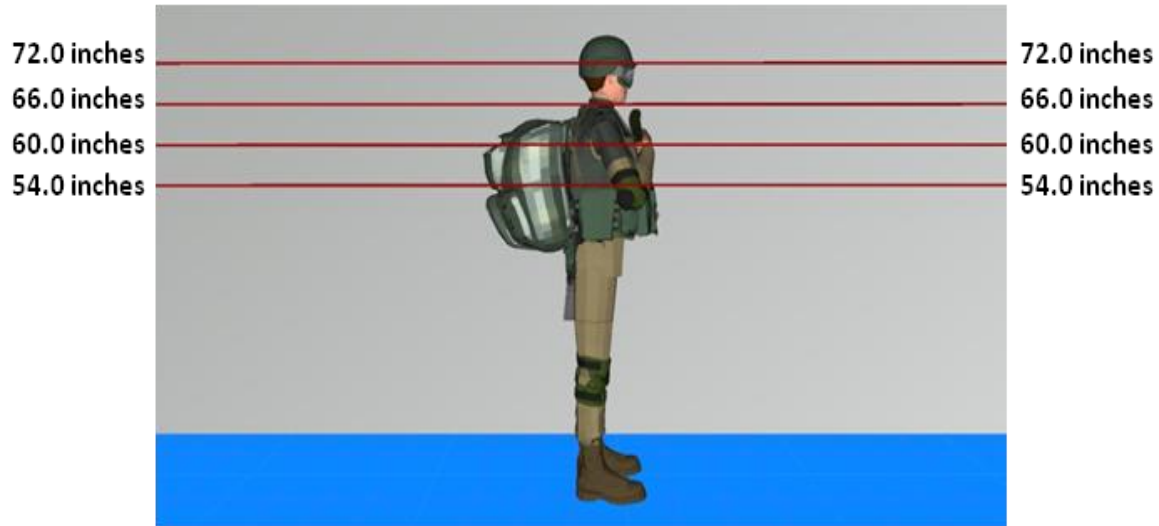


Figure 13. Comparison of 95th percentile male (stature) and cabin ceiling heights.

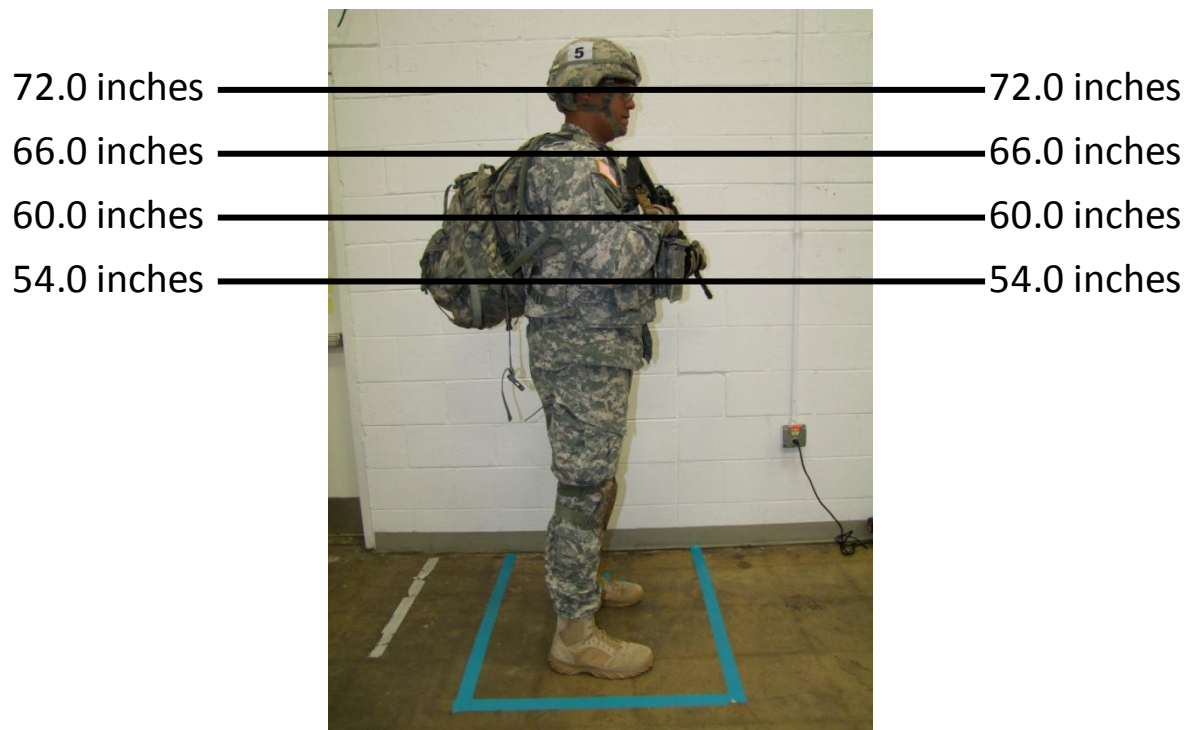


Figure 14. Comparison of largest male and cabin ceiling heights.

### 3.3 Floor Widths

The benches were moved inboard to assess the impact of a 68.0-in. floor width on ingress/egress, body movement restriction, and space requirements for the Soldier's gear. All Soldiers were able to ingress and egress the mockup cabin with the floor width of 68.0 in. Table 12 summarizes the



Soldier responses about difficulty of ingress/egress, body movement restriction, and space requirements for the Soldier's gear (versus the 72.0-in. floor width).

Table 12. Floor width questionnaire responses.

<b>68.0-in. Floor Width Assessment. Cabin Height = 72.0 in. All Soldiers fit in seat space.</b>				<b>Comments</b>
Aisle width = 33.0 in. between front edge of bench to front edge of other bench.	Much more difficult	Somewhat more difficult	About the same	—
How much more difficult was it to ingress vs. floor width of 72.0 in.?	0%	22%	78%	—
How much more difficult was it to egress vs. floor width of 72.0 in.	11%	33%	56%	More time to egress; when stood up, knocked into each other and stepped on bag; had to stagger stand-up times to not get jammed up.
How restrictive was body movement (Soldier sitting erect) for:	Very Restrictive	Somewhat Restrictive	Not Restrictive	—
Leg movement (both legs)	56%	31%	13%	—
Positioning of feet	56%	6%	38%	—
<b>General Comments</b>				
Gear that had to be repositioned for seating: rucksack; moved M192 tripod to vertical position from horizontal; problems putting javelin down—needed to wait to get up due to Javelin; canteen had to be repositioned; had to move squad automatic weapon to left-hand side.				
Problems with stowage of other gear (e.g., Javelin command launch unit [CLU]): none reported.				
Elapsed time for all Soldiers to ingress mockup and be seated = 22.0 s				
Elapsed time for all Soldiers to egress mockup = 12.0 s				

Twenty-two percent of the Soldiers reported that it was “somewhat more difficult” to ingress the cabin with the floor width of 68.0 in. (versus 72.0 in.). Seventy-eight percent of the Soldiers reported that the difficulty of ingress was “about the same.” Eighty-seven percent of Soldiers reported that their leg movement was “very restricted” (56%) or “somewhat restricted” (31%). Sixty-two percent reported that positioning of their feet was “very restricted” (56%) or “somewhat restricted” (6%). Three Soldiers commented about problems they experienced during egress (e.g., body contact). Six comments were provided about gear that had to be repositioned before being seated.

The Soldiers could not traverse the aisleway due to lack of space for foot placement. The rucksacks, weapons and legs/feet of the Soldiers took all available space on the cabin floor and prohibited walking in the aisleway, the width of which was 33.0 in. as measured between the front edge of one bench to the front edge of the other bench. When the benches were configured to represent a floor width of 72.0 in. (37.25-in. aisleway width), the largest Soldier was able to traverse the aisleway with some difficulty due to restricted space for foot placement.

The cross-aisle way knee clearance between two of the larger Soldiers (buttock-knee length) varied from 6.0 to 8.0 in. depending on upper-body slump and positioning of their legs. For the 72.0-in. floor width, the cross-aisle way knee clearance between the same (larger) Soldiers varied from 10.0 to 12.0 in.

Figure 15 illustrates the differences in leg room and gear stowage on the cabin floor for 68.0 versus 72.0 in. It took the Soldiers 22.0 s to ingress the cabin and be seated and 12.0 s to egress the cabin.

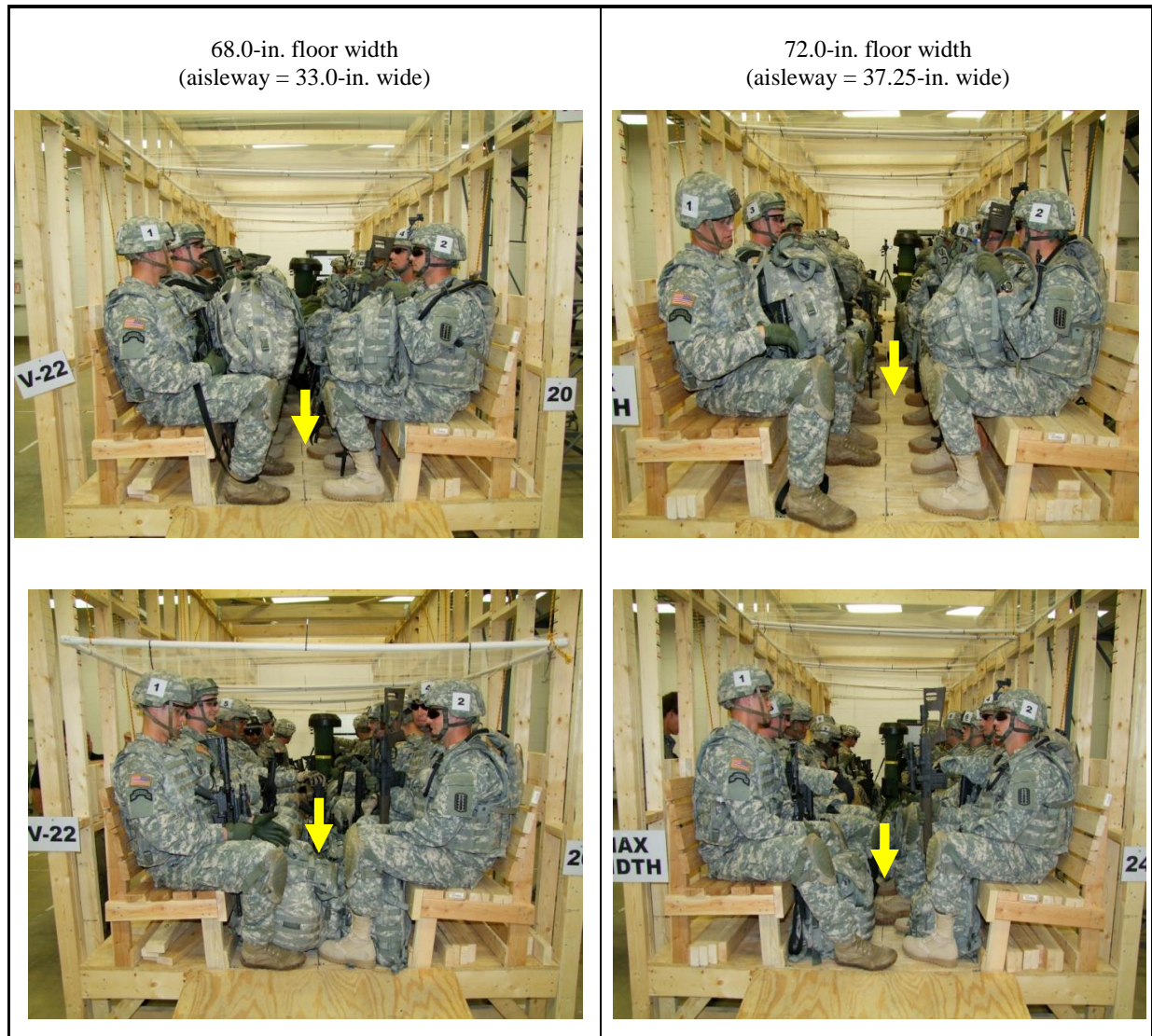


Figure 15. 68.0- vs. 72.0-in. floor width.

### 3.3.1 Large Soldiers

All large Soldiers (N = 6) reported that leg movement and positioning of their feet was “very restrictive.” Eighty-three percent reported that ingress “was about the same” level of difficulty compared with the 72.0-in. floor width while 66% reported that ingress was “about the same” level of difficulty.

### 3.3.2 Upper-Medium-Size Soldiers

One upper-medium Soldier reported that leg movement and positioning of his feet was “very restrictive.” The other Soldier reported that leg movement was “somewhat restrictive” and positioning of his feet was “not restrictive.” One Soldier reported that ingress and egress was “somewhat more difficult” while the other Soldier reported that ingress and egress was “about the same” level of difficulty compared to the 72.0-in. floor width.

### 3.3.3 Lower-Medium-Size Soldiers

Seventy-five percent reported that leg movement was “very restrictive” (50%) or “somewhat restrictive” (25%). Fifty percent reported that positioning of their feet was “very restrictive” while 50% reported that it was “not restrictive.” Seventy-five percent reported that ingress “was about the same” level of difficulty compared with the 72.0-in. floor width while 50% reported that egress was “somewhat more difficult” or “about the same” (50%).

### 3.3.4 Small Soldiers

Eighty-three percent of the small Soldiers (N = 5) reported that leg movement was “very restrictive” (33%) or “somewhat restrictive” (50%). Fifty percent reported that positioning of their feet was “very restrictive (33%) or “somewhat restrictive” (17%). Eighty-three percent reported that ingress “was about the same” level of difficulty compared with the 72.0-in. floor width while 50% reported that egress was “about the same” level of difficulty.

Table 13 shows floor width questionnaire responses by body size.

Table 13. Questionnaire responses by body size for floor width.

Soldier Size	How much more difficult was it to <u>ingress</u> compared to the 72.0 inch floor width			Leg Movement			Feet Positioning			How much more difficult was it to <u>egress</u> compared to the 72.0 inch floor width		
	Much More Difficult	Somewhat More Difficult	About the Same	Very Restrictive	Somewhat Restrictive	Not Restrictive	Very Restrictive	Somewhat Restrictive	Not Restrictive	Much More Difficult	Somewhat More Difficult	About the Same
Large	0%	17%	83%	100%	0%	0%	100%	0%	0%	17%	17%	66%
Upper Medium	0%	50%	50%	50%	50%	0%	50%	0%	50%	0%	50%	50%
Lower Medium	0%	25%	75%	50%	25%	25%	50%	0%	50%	0%	50%	50%
Small	0%	17%	83%	33%	50%	17%	33%	17%	50%	17%	33%	50%

### **3.4 Fore and Aft Seating Configuration**

The benches were reconfigured to fore and aft seating (figures 16–18) to assess the impact on ingress/egress, body movement restriction, and gear stowage for groups of 9 and 14 Soldiers. The fore and aft seating configuration was similar to the seating in the UH-60 Black Hawk helicopter (benches were perpendicular to the centerline of the mockup). Three benches were used during this assessment. Two benches were 60.0 in. long and one bench was 80.0 in. long. The seating configuration was 4-3-3-4 for the group of 14 Soldiers and 3-3-3 for the group of 9 Soldiers. The distance between the front edge of each bench to the front edge of the corresponding bench was 28.0 in. for all trials. No seat dividers were used during this part of the assessment. All Soldiers performed ingress and egress through the right front cabin door. The doors required for side door ingress and egress (similar to the UH-60 Black Hawk) were not included in the delivered mockup. Therefore, the benches were reconfigured (in two configurations) to simulate the fore and aft seating arrangement. One configuration was with the seating arranged for 9 and 14 Soldiers with the benches positioned perpendicular to the centerline of the mockup. The other configuration was with the benches positioned at the aft end of the mockup parallel to the centerline of the mockup, but with only half the seating that was in the first configuration. Egress times were taken with these soldiers exiting the ramp to simulate an exit through one side of a side door configured aircraft. The ceiling height was adjusted for each simulation.

#### **3.4.1 The 14-Soldier Configuration**

All Soldiers were able to ingress and egress the cabin and fit in their allotted seat space. Ingress and egress were cumbersome for the Soldiers seated in the furthest aft bench and the Soldiers seated across from (and facing) the aft bench. This was due to lack of doors leading directly to the furthest aft benches. The Soldiers had to maneuver between a small gap between the benches and cabin wall to access the furthest aft benches.

The majority of Soldiers (79%–85%) reported that their upper-body movement was not restricted (table 14). Eighty-six percent of Soldiers reported that their leg movement was “very restricted” (43%) or “somewhat restricted” (43%). Seventy-one percent reported that positioning of their feet was “very restricted” (42%) or “somewhat restricted” (29%). It took the Soldiers an average of 12.0 s to ingress the cabin and be seated and 9.0 s to egress the cabin. The Soldiers performed ingress and egress trials for cabin ceiling heights of 54.0, 60.0, and 66.0 in.



9 Soldiers



14 Soldiers (aisleway view)



14 Soldiers



Figure 16. 9- and 14-troop configuration.



Figure 17. Overhead view of 14-soldier configuration.



Figure 18. Overhead view of nine-soldier configuration.

Table 14. Fore/aft seating questionnaire responses.

<b>Fore/Aft Seating Configuration for 14 Soldiers. Cabin height = 66 in. Troop configuration = 4-3-3-4. Two benches were 60 in. long and one was 80 in. long. Distance between benches = 28 in. No seat dividers. All Soldiers fit in seat space</b>				<b>Comments</b>
How restrictive was body movement (Soldier sitting erect) for:	Very restrictive	Somewhat restrictive	Not restrictive	—
Torso pivot	0%	14%	85%	—
Lateral torso lean (left and right)	0%	14%	85%	—
Arm movement (both arms)	7%	14%	79%	—
Leg movement (both legs)	43%	43%	14%	—
Positioning of feet	42%	29%	29%	—
<b>Other Comments</b>				
Worn gear that had to be repositioned for seating: none reported.				
Problems with stowage of other gear (e.g., CLU): Lifted CLU. Could not get to front facing rear seat (mockup limitation).				
Average elapsed time for Soldiers to ingress mockup and be seated for all configurations = 12.0 s Average elapsed time for Soldiers to egress mockup and be seated for all configurations = 9.0 s				
<b>Fore/Aft Seating Configuration for Nine Soldiers. Cabin height = 66 in. Troop configuration = 3-3-3. Two benches were 60 in. long. Distance between benches = 28 in. No seat dividers. All Soldiers fit in seat space.</b>				<b>Comments</b>
How restrictive was body movement (Soldier sitting erect) for:	Very restrictive	Somewhat restrictive	Not restrictive	—
Torso pivot	11%	56%	33%	—
Lateral torso lean (left and right)	11%	56%	33%	—
Arm movement (both arms)	22%	33%	45%	—
Leg movement (both legs)	67%	11%	22%	—
Positioning of feet	67%	11%	22%	—
<b>Other Comments</b>				
Worn gear that had to be repositioned for seating: none reported.				
Problems with stowage of other gear (e.g., CLU): none reported.				
Average elapsed time for Soldiers to ingress mockup and be seated for all configurations = 12.0 s. Average elapsed time for Soldiers to egress mockup and be seated for all configurations = 9.0 s.				

### 3.4.2 9-Soldier Configuration

All Soldiers were able to ingress and egress the cabin and fit in their allotted seat space. The majority of Soldiers (55%–67%) reported that their upper-body movement was “very” or “somewhat” restricted. Seventy-eight percent of Soldiers reported that their leg movement was “very restricted” (67%) or “somewhat restricted” (11%). Seventy-eight percent reported that positioning of their feet was “very restricted” (67%) or “somewhat restricted” (11%).



### 3.4.3 Fore and Aft Seating (Ingress and Egress)

The mockup did not have side doors that allowed a comparative assessment of ingress and egress to a UH-60 cabin. Therefore, the benches were reconfigured parallel to the centerline of the mockup to assess ingress and egress (figure 19) similar to a UH-60. Seven Soldiers conducted ingress and egress trials at cabin ceiling heights of 54.0, 60.0, and 66.0 in. The ingress and egress times are listed in table 15.



Figure 19. Ingress and egress for fore and aft seating configuration.

Table 15. Fore and aft seating (ingress and egress).

Fore and Aft Seating Configuration			
No. of Soldiers	Cabin Ceiling Height (in.)	Ingress Time (s)	Egress (s)
7	54	14	9
7	60	11	8
7	66	11	8



### 3.5 Cabin Door Widths

The largest male Soldier performed ingress and egress trials through the right front cabin door (figure 20). The height of the door was 72.0 in. The width of the door varied 28.0, 32.0, and 36.0 in. for the trials. His bideltoid breadth was representative of the 99th percentile male and his forearm-to-forearm breadth was representative of the 91st percentile male. The Soldier was able to ingress and egress through the cabin door. He had to assume a slightly stooped posture during the trials to ensure that he did not strike his helmeted head against the bottom of the upper door frame. The Soldier had to progressively draw his arms and shoulders more inward toward the center of his body as the door width was decreased from 36.0 to 32.0 to 28.0 in. At the 28.0-in. door width, the ammo pouch on his right side occasionally contacted the side of the door frame. Soldiers would experience increasing difficulty maneuvering weapons through the cabin door as the door widths were decreased.

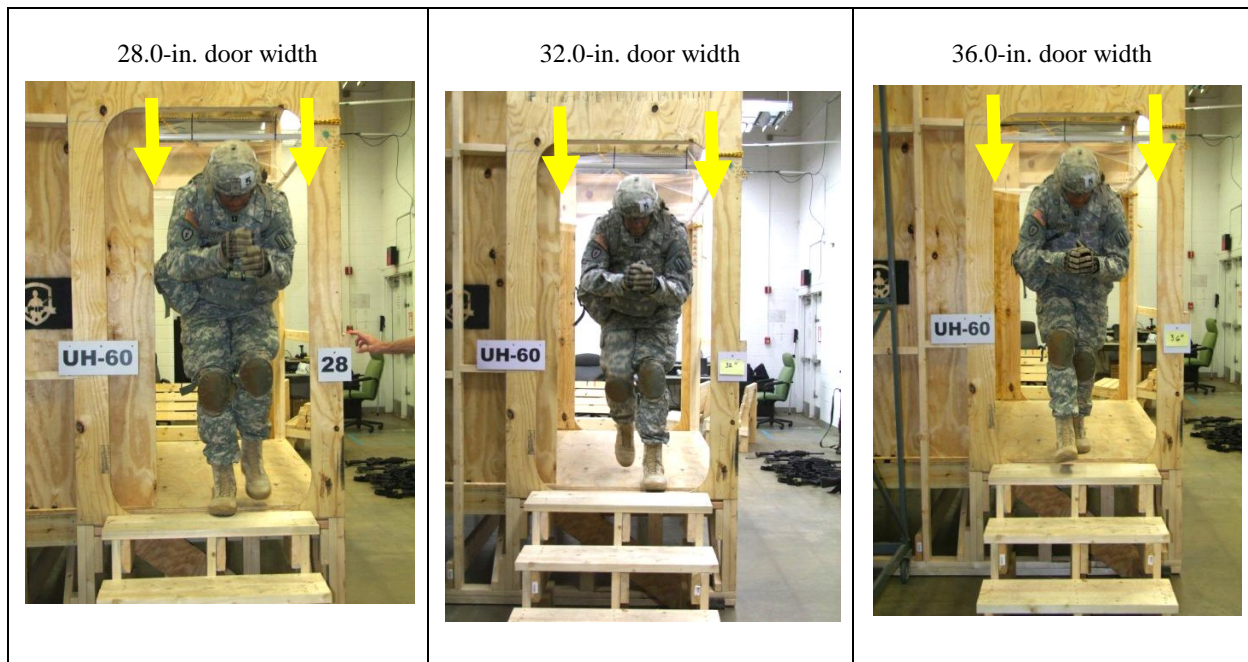


Figure 20. Large male ingress and egress of cabin door.

### 3.6 Emergency Egress

The Soldiers received a short brief about the emergency egress trials and the need for deliberate and safe movement during the trials. Per the MIL-STD 1472D<sup>3</sup> requirement that half of the exits be blocked, the Soldiers were instructed to use only one exit (left front door or ramp) to egress the mockup. Spotters were assigned to the exit that was being used for the emergency egress to

<sup>3</sup> MIL-STD-1472D. *Human Engineering, Design Criteria for Military Systems, Equipment, and Facilities*, Department of Defense Design Criteria Standard 1989.

reduce the probability of injury due to a fall. Steps were placed at the forward left and right door exits for the Soldiers to use during egress to further reduce probability of an injury due to a fall. After a short countdown, the Soldiers performed emergency egress through the specified exit.

The emergency egress trials were performed for groups of 9, 14, and 18 Soldiers (table 16). Cabin ceiling height varied between 60.0 and 66.0 in. to determine any impact of available vertical space on egress. The floor width was 68.0 in. The emergency exit requirement states that passengers must be able to exit the aircraft in 60 s (or less) with half of the exits blocked. Figure 21 shows Soldiers conducting emergency egress.

The emergency egress requirement was met for all groups of Soldiers and cabin ceiling heights. The average emergency egress times were 7–19.5 seconds.

Table 16. Emergency egress time data.

<b>Emergency Egress Trials (60-s egress requirement with half of all exits blocked)</b>				
<b>Egress Exit</b>	<b>No. of Troops</b>	<b>Cabin Ceiling Height (in.)</b>	<b>Egress Time (s)</b>	<b>Emergency Egress Requirement</b>
Ramp	18	60	15	—
Ramp	18	66	14	—
—	—	—	14.5 (average)	Met
—	—	—	—	—
Ramp	14	60	11	—
Ramp	14	66	10	—
—	—	—	10.5 (average)	Met
—	—	—	—	—
Ramp	9	60	7	—
Ramp	9	66	7	—
—	—	—	7 (average)	Met
—	—	—	—	—
Left front door	18	60	19	—
Left front door	18	66	20	—
—	—	—	19.5 (average)	Met
—	—	—	—	—
Left front door	14	60	15	—
Left front door	14	66	15	—
—	—	—	15 (average)	Met
—	—	—	—	—
Left front door	9	60	12	—
Left front door	9	66	11	—
—	—	—	11.5 (average)	Met



Figure 21. Emergency egress via ramp.

### 3.7 Modeling of Space Requirements

ARL-HRED conducted modeling to assess seat space requirements for Soldiers in the medium cabin variant. Figure 22 depicts usable space for large male Soldiers for 26.0-in. seat space width. The red arrows depict the space between shoulders and upper torso for the Soldiers. The space requirements identified by modeling were comparable to the space requirements reported by the largest Soldiers (and observed by ARL-HRED and AFDD) during the cabin mockup assessment. The gear used by the Soldiers during the mockup assessment and the gear used in the modeling were not identical. In addition, the modeling was conducted with rucksacks on the backs of the Soldiers for ingress and egress. The Soldiers wore the rucksacks on the front of their torso during the mockup assessment during ingress and egress. This allowed them to get into the seats more quickly and lower the rucksacks to the floor.



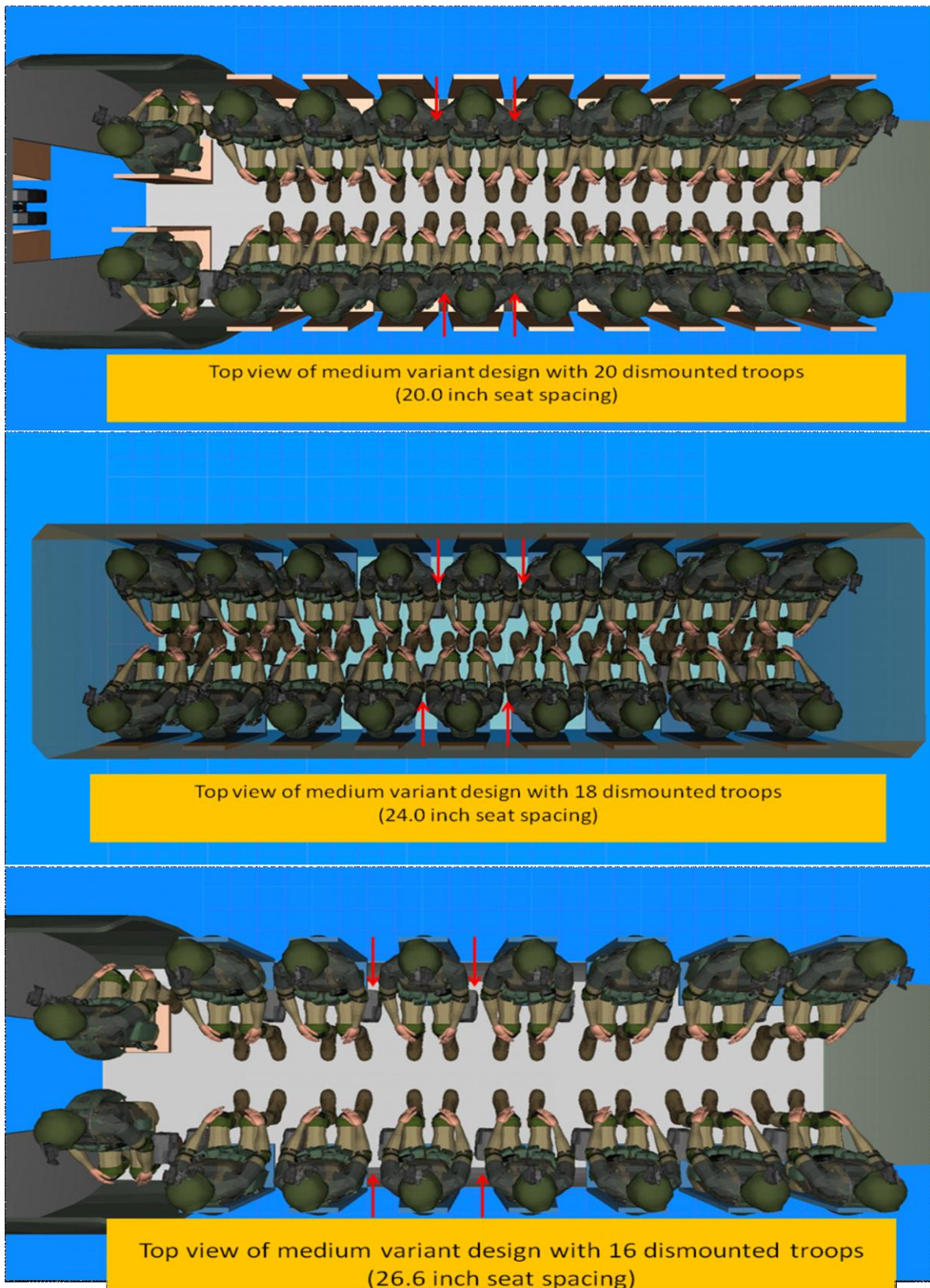


Figure 22. Modeling of seat space widths for large soldiers.

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## **4. Summary and Recommendations**

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### **4.1 Seat Space Widths**

Fit was very tight for the largest Soldiers in the 20.0-in. seat space. The majority of Soldiers reported that upper-body, arm, leg, and foot movement was restricted in the 20.0-in. seat space. Most Soldiers had to maintain a confined and static seating position and did not appear to have adequate space to effectively reposition their upper torso, arms, legs, and feet to minimize fatigue when seated in the 20.0-in. seat width. The Soldiers reported less restriction of upper-body, arm, and, foot positioning for the 22.0-in. seat space with (about) half of the Soldiers reporting that leg movement was restricted. The majority of large Soldiers reported that upper and lower-body movement was restricted at 22.0 in. The three large Soldiers used to assess the 23.0-in. seat space reported moderate upper-body restriction and commented that it would be the minimally acceptable seat space width if they were seated next to other large Soldiers. Most Soldiers reported that upper-body, arm, leg, and foot movement was not restricted for the 24.0- and 26.0-in. seat space. The Soldiers appeared to have adequate space to reposition their upper torso, arms, legs, and feet to minimize muscle tension and fatigue in the 24.0- and 26.0-in. seat width space. The ability to effectively reposition their body during flight to minimize muscle tension and fatigue (e.g., improved blood flow to arms and legs) would be especially important if Soldiers were required to physically exert themselves upon immediate exit from the aircraft (e.g., combat operations). This will be important for the FVL/JMR because of the longer ranges that the aircraft would fly compared with current aircraft.

Recommendation: Based on the seat space assessment, discussions with the Soldiers during the assessment, and modeling conducted by ARL-HRED, a seat space width of 23.0 in. is the recommended minimum acceptable size to accommodate the body size distribution of Soldiers and combat gear that were used during this assessment.

### **4.2 Cabin Ceiling Heights**

The cabin ceiling heights that were assessed included 54.0, 60.0, 66.0, and 72.0 in. All Soldiers had to significantly bend their torso and knees and adopt a stooped posture during ingress and egress at the cabin ceiling height of 54.0 and 60.0 in. The larger Soldiers had to adopt a very stooped posture to ingress (and egress) the cabin at 54.0 and 60.0 in. The stooped posture combined with most Soldiers being top-heavy (due to weight of their gear on their torsos) increases the probability that they would lose their balance and fall during ingress and egress. The weight of the combat gear that the Soldiers wore during the assessment ranged from 57 (60-mm assistant gunner) to 99 lb (assistant gunner). The stooped posture also increases the probability of lower back strain. At the 54.0-in. ceiling height, one Soldier tripped and fell (in the aisle) during egress and the NVG mount on the helmet of one Soldier struck the cabin

ceiling, which caused his head to be jerked back during egress. The majority of Soldiers inadvertently pushed their helmets and/or upper backs through the cabin ceiling netting during ingress and egress at the 54.0-in. ceiling height due to the very limited vertical space between the ceiling and the cabin floor. At the 60.0-in. ceiling height, the larger Soldiers inadvertently pushed their helmets and/or upper backs through the cabin ceiling netting during ingress and egress. The majority of Soldiers reported that it was difficult to carry and maneuver their gear at the 54.0- and 60.0-in. heights. Loading litters, supplies, and equipment, and performing critical care tasks for patients by flight medics (e.g., chest compressions), would also be difficult and time-consuming at the 54.0- and 60.0-in. heights due the limited vertical space to maneuver in the cabin. The Soldiers were able to stand more upright at the 66.0-in. ceiling height, and the majority reported they experienced no difficulty when carrying and maneuvering their gear during ingress. Eighty-eight percent (N = 16) of the Soldiers reported that they did not have to bend their torso and knees (or adopt a stooped posture) during ingress at the 72.0-in. cabin ceiling height. They reported that it was not difficult to carry and maneuver their gear during ingress. Ingress and egress times were progressively faster as the cabin ceiling heights were raised to a higher position. The mockup had no protrusions from the interior walls such as mounting points, brackets, or handles. Such items may hamper ingress and egress in the production aircraft.

**Recommendation:** A minimum cabin ceiling height of 66.0 in. is recommended to accommodate the body size distribution of Soldiers and combat gear that were used during the assessment. A cabin ceiling height of 66.0 in. provides adequate clearance for Soldiers to ingress and egress the aircraft in a more upright posture, carry and maneuver their gear, load supplies and equipment, and egress the aircraft. It would also reduce the probability of lower back strain due to stooped posture compared with the 54.0- and 60.0-in. ceiling heights.

### **4.3 Floor Widths**

At the 68.0-in. floor width, leg movement and positioning of feet was restricted for most of the Soldiers. The Soldiers could not traverse the aisleway due to lack of space for foot placement. When the benches were configured to a floor width of 72.0 in., the largest Soldier was able to traverse the aisleway with difficulty (due to restricted space for foot placement). The majority of Soldiers reported that the difficulty of ingress was “about the same” for the 68.0-in. floor width versus the 72.0-in. width. About half of the Soldiers reported that the difficulty of egress was more difficult for the 68.0-in. floor width versus the 72.0-in. width. The 72.0-in. floor width provided increased space for Soldiers to reposition their legs and feet during flight to minimize muscle tension and fatigue. It also provided increased space to stow gear and limited space to traverse the aisle way.

Recommendation: A minimum floor width of 72.0 in. (aisleway width of 37.25 in.) is recommended to provide space for Soldiers to stow their packs, reposition their legs and feet, traverse the aisle way during ground and flight operations, and load supplies and equipment.

#### **4.4 Fore and Aft Seating Configuration**

All Soldiers (N = 14) were able to ingress and egress the cabin and fit in their allotted seat space. The majority of Soldiers reported that their upper-body movement was not restricted but that their leg movement and foot positioning was restricted. All Soldiers (N = 9) were able to ingress and egress the cabin and fit in their allotted seat space. The majority of Soldiers reported that their upper-body and leg movement and positioning of their feet was restricted.

Recommendation: A minimum of ceiling height of 66.0 in. for the fore and aft seating configuration is recommended. The minimum door size for this configuration was not determined during this assessment.

#### **4.5 Cabin Door Widths**

The largest male Soldier performed ingress and egress trials through the right front cabin door. The height of the door was 72.0 in. The width of the door varied 28.0, 32.0, and 36.0 in. for the trials. He had to assume a slightly stooped posture during the trials to ensure he did not strike his helmeted head against the bottom of the upper door frame. The Soldier had to draw his shoulders inward to his chest (more) as the door width was decreased from 36.0 to 32.0 to 28.0 in. At the 28.0-in. door width, the ammo pouch on his right side contacted the side of the door frame.

Recommendation: A minimum cabin door width of 32.0 in. is recommended to provide adequate space for Soldiers to safely and quickly ingress and egress with their combat gear.

#### **4.6 Emergency Egress**

The emergency egress requirement of 60 s (or less) was met for all groups of Soldiers and cabin ceiling heights. The average emergency egress times were 7–19.5 s.

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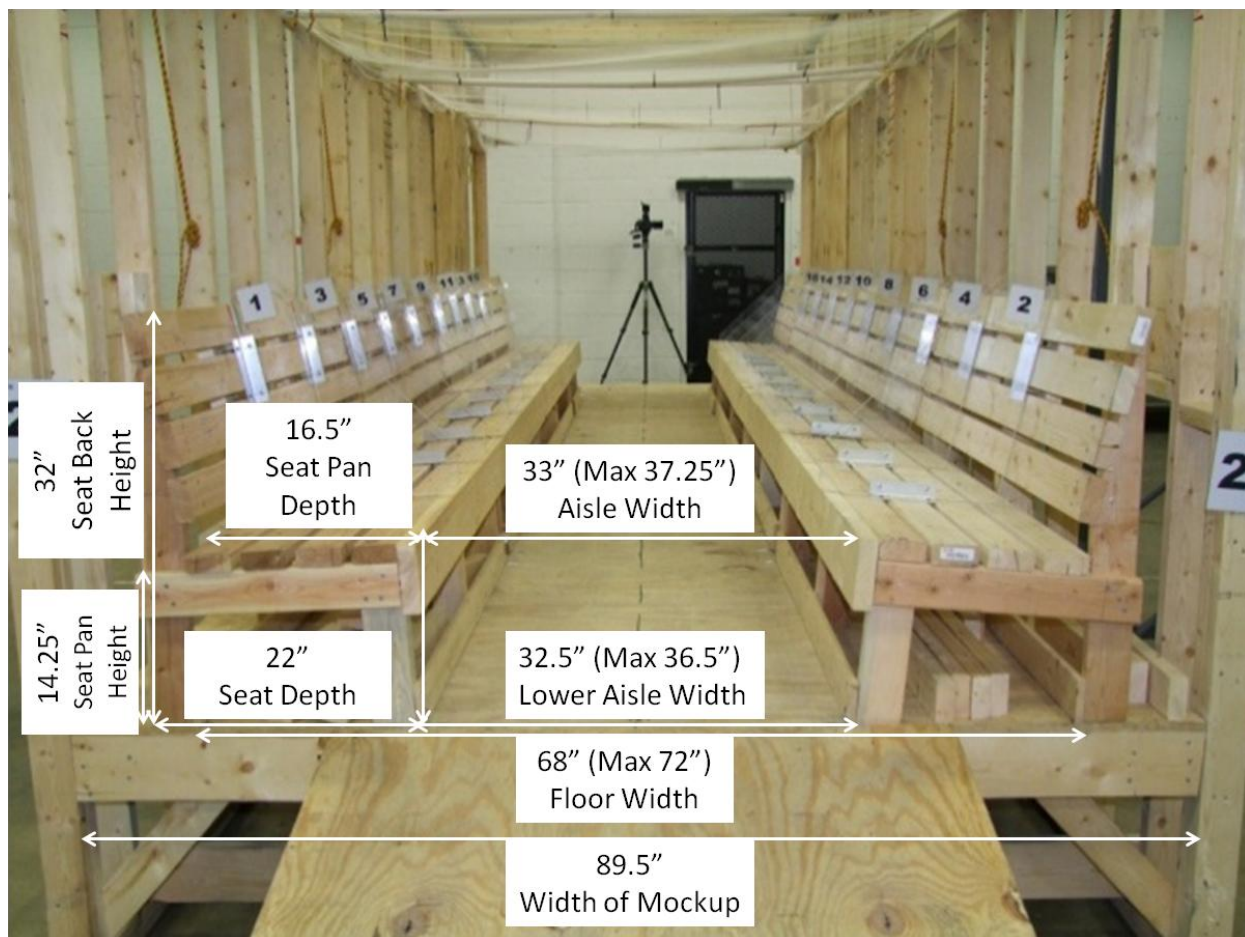
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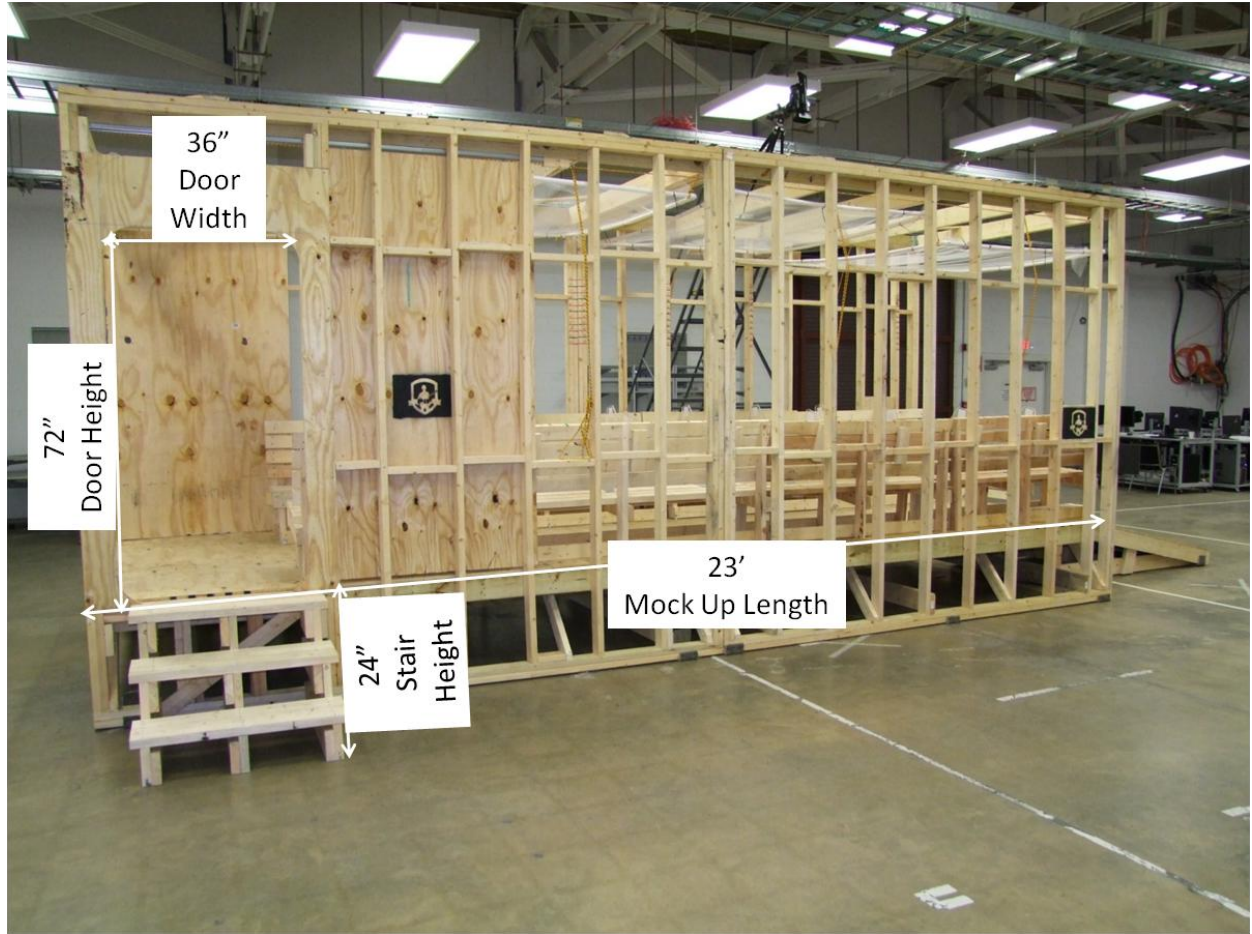
## **Appendix A. Mockup Dimensions (all measurements in inches and feet)**

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This appendix appears in its original form, without editorial change.







Cabin ceiling height adjustment markers.

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## **Appendix B. Rifle Platoon Basic Load (72-H)**

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This appendix appears in its original form, without editorial change.

Taken from unpublished 2012 briefing: U.S. Army Rifle Platoon Basic Load, Operation Enduring Freedom XII, U.S. Army 82nd Airborne Division, Fort Bragg, NC.



## Platoon Leader 96Lbs

- M4 (7x30rd Magazines)
- PRC-152 (batteries x3)
- PVS-20
- Trans AP
- Pin Flare kit
- GPS
- VS-17 Panel
- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit
- 5590 x 2







## Platoon Sergeant 98Lbs



- M4 (7x30rd Magazines)
- PRC-152 (batteries x3)
- PVS-20
- Trans AP
- Smoke Grenade
- GPS

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit
- 5590 x 2





## Squad Leader 100Lbs



- M4 (7x30rd Magazines)
- PRC-152 (batteries x3)
- PVS-20
- Trans AP
- M67 Frag Grenade
- Pin Flare kit
- Smoke Grenade
- HIIDE System
- GPS
- VS-17 Panel
- 7.62, 100rds
- EPW kit

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit
- 5590 x 2







## Team Leader 97Lbs



- M4 (7x30rd Magazines)
- PRC-152 (batteries x3)
- PVS-14
- M67 Frag Grenade
- Smoke Grenade
- Thor
- GPS

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit
- 5590 x 2





## Grenadier 105Lbs



- M4 (7x30rd Magazines)
- M 320 Grenade Launcher
- PVS-14
- M67 Frag Grenade
- Smoke Grenade
- Goldie
- 40mm, white star cluster x2
- 40mm, HEDP x 10
  
- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit
- 5590 x 2



# Automatic Rifleman 118Lbs

- M249 (800 rounds)
- PVS-14
- M67 Frag Grenade
- Star Cluster
- Combat Lifesaver Bag

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit



# Rifleman/SDM 111Lbs

- EBR/M14 (7x20rd Magazines)
- PVS-14
- M67 Frag Grenade
- MineHound



- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit
- 5590 x 2

# Machine Gunner 103Lbs

- M240L (300 Rounds)
- M9 (3x15 round magazines)
- PVS-14

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit







## Assistant Gunner 116Lbs



- M4 (7x30rd Magazines)
- PVS-14
- 7.62, 400 rounds
- Spare Barrel
- Tripod

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit





## Radio Telephone Operator 119Lbs



- M4 (7x30rd Magazines)
- PVS-14
- ASIP radio
- 5590 Batteries (4)
- SKL
- DAGR GPS

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit





## Forward Observer 96Lbs



- M4 (7x30rd Magazines)
- PVS-14
- Smoke Grenade
- PRC-152 (batteries x3)
- DAGR GPS
- VS-17 Panel

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit
- 5590 x 2





# Anti-Tank/M3 Gunner 102Lbs

- M4 (7x30rd Magazines)
- PVS-14
- M3 Carl Gustav (with 4 Rounds)

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit





- M4 (7x30rd Magazines)
- PVS-14
- Aid Bag
- Aid Belt

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit



# 60mm Gunner 115Lbs

- M4 (7x30rd Magazines)
- PVS-14
- M224 60mm Cannon
- M9 Baseplate
- 60mm HE (1rd)
- M9 (2 15rds Magazines)

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Eberle Stock (gun bag)
- Knee Pads
- Poncho
- Poncho Liner
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit





## 60mm Assistant Gunner 105Lbs



- M4 (7x30rd Magazines)
- PVS-14
- 60mm HE (5rds)

- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit





# LLVI Team Member 151Lbs

- M4 (7x30rd Magazines)
- PVS-14
- (Ruck 1) PRD-13 Brain w/Antenna
- (Ruck 1) 5590 Batteries (2)
- (Ruck 1) Harris 152
- (Ruck 2) DF Antenna w/cable
- (Ruck 2) Binoculars
- (Ruck 2) 5590 Batteries (6)
- Plate Carrier w/ Plates
- ACH
- Eye Protection
- Gloves
- Medium Ruck
- Knee Pads
- Poncho
- Poncho Liner
- Socks, 1 Pair
- Water, 5 liters
- MREs, 6 field stripped
- Weapons Cleaning Kit
- Hygiene Kit



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## **Appendix C. Anthropometric Measurement Data (all measurements in centimeters except weight)**

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This appendix appears in its original form, without editorial change.



Radio Telephone Oper.					Rifleman				
	w/o Gear	%-ile	Gear	Delta		w/o Gear	%-ile	Gear	Delta
Weight	207	92	283	76	Weight	187	74	250	63
Stature	183.2	87	188	4.8	Stature	174.8	45	181.8	7
Sitting Height	95.8	89	95.9	0.1	Sitting Height	92	56	92	0
Bideltoid Breadth	53.4	95	59.1	5.7	Bideltoid Breadth	50.6	73	54	3.4
Forearm to Forearm	58.3	80	68.4	10.1	Forearm to Forearm	55.6	60	66.5	10.9
Chest Depth	26	79	38.5	12.5	Chest Depth	27.3	91	49.6	22.3
Hip Breadth Sitting	39.1	82	-----	-----	Hip Breadth Sitting	38.2	75	-----	-----
Buttock-Knee Length	64.5	84	102	37.5	Buttock-Knee Length	62.1	58	95.6	33.5
Widest At Waist w/ Gear	-----	-----	51	-----	Widest At Waist w/ Gear	-----	-----	50.6	-----
Squad Leader					Platoon SGT				
	w/o Gear	%-ile	Gear	Delta		w/o Gear	%-ile	Gear	Delta
Weight	210	93	277	67	Weight	208	93	280	72
Stature	187.4	96	194.5	7.1	Stature	185.9	92	191.7	5.8
Sitting Height	99.6	99	102.7	3.1	Sitting Height	97.4	96	99.8	2.4
Bideltoid Breadth	54.1	97	57.7	3.6	Bideltoid Breadth	51.2	79	56.7	5.5
Forearm to Forearm	60.1	89	68.2	8.1	Forearm to Forearm	56.7	70	65.4	8.7
Chest Depth	26.1	80	35.4	9.3	Chest Depth	26.4	84	37	10.6
Hip Breadth Sitting	41.6	96	-----	-----	Hip Breadth Sitting	42.3	98	-----	-----
Buttock-Knee Length	63.4	74	100.3	36.9	Buttock-Knee Length	65.5	89	99.7	34.2
Widest At Waist w/ Gear	-----	-----	42.1	-----	Widest At Waist w/ Gear	-----	-----	55.4	-----
Platoon Leader/Medic					Low Level Voice Intercept				
	w/o Gear	%-ile	Gear	Delta		w/o Gear	%-ile	Gear	Delta
Weight	258	99	332	74	Weight	194	82	265	71
Stature	193.6	99	198	4.4	Stature	179.1	70	185.4	6.3
Sitting Height	96.9	92	96.1	-0.8	Sitting Height	93.8	75	97.5	3.7
Bideltoid Breadth	56.3	99	59.6	3.3	Bideltoid Breadth	51.1	79	56	4.9
Forearm to Forearm	60.6	91	72	11.4	Forearm to Forearm	58.6	83	67.5	8.9
Chest Depth	30.4	99	42	11.6	Chest Depth	26.5	85	41	14.5
Hip Breadth Sitting	44.2	99	-----	-----	Hip Breadth Sitting	38.3	75	-----	-----
Buttock-Knee Length	71.5	99	104	32.5	Buttock-Knee Length	64.4	83	105.4	41
Widest At Waist w/ Gear	-----	-----	51.8	-----	Widest At Waist w/ Gear	-----	-----	50.1	-----
M203 Grenadier					Medic				
	w/o Gear	%-ile	Gear	Delta		w/o Gear	%-ile	Gear	Delta
Weight	187	74	254	67	Weight	203	89	266	63
Stature	166.2	7	171.6	5.4	Stature	183.1	87	187.4	4.3
Sitting Height	84.5	3	89.2	4.7	Sitting Height	95	82	95.5	0.5
Bideltoid Breadth	52	88	54.4	2.4	Bideltoid Breadth	50.5	70	55.8	5.3
Forearm to Forearm	58.5	83	61.2	2.7	Forearm to Forearm	53.5	42	61.5	8
Chest Depth	27.3	92	39.2	11.9	Chest Depth	26.8	87	39.8	13
Hip Breadth Sitting	38.4	77	-----	-----	Hip Breadth Sitting	40.4	92	-----	-----
Buttock-Knee Length	61	44	93.6	32.6	Buttock-Knee Length	66	92	98.2	32.2
Widest At Waist w/ Gear	-----	-----	42.7	-----	Widest At Waist w/ Gear	-----	-----	49.8	-----

Note: Widest at waist is the measurement for the gear worn on the waist. This measurement was taken at the widest width of gear worn on the waist and was in lieu of hip breadth sitting (with gear). Sitting height and stature measurements were variable for certain Soldiers due to upper torso slump when wearing combat gear. The delta for buttock-knee length includes the measurement for the assault/hydration packs and body armor added to the buttock-knee length.

Assistant Gunner					Anti-Tank Javelin				
	w/o Gear	%-ile	Gear	Delta		w/o Gear	%-ile	Gear	Delta
Weight	192	80	291	99	Weight	147.6	14	220	72.4
Stature	181	80	185.9	4.9	Stature	161.2	2	167.4	6.2
Sitting Height	95.7	87	96.5	0.8	Sitting Height	82	1	85.8	3.8
Bideltoid Breadth	51.8	85	56.8	5	Bideltoid Breadth	49	49	56.1	7.1
Forearm to Forearm	54.6	52	66.5	11.9	Forearm to Forearm	54.8	54	59.6	4.8
Chest Depth	28.1	96	38.5	10.4	Chest Depth	23.6	40	35.3	11.7
Hip Breadth Sitting	38.3	75	-----	-----	Hip Breadth Sitting	36	44	-----	-----
Buttock-Knee Length	65.6	90	102.9	37.3	Buttock-Knee Length	58.2	13	93.5	35.3
Widest At Waist w/ Gear	-----	-----	52.6	-----	Widest At Waist w/ Gear	-----	-----	49.5	-----
Team Leader					Radio Telephone Oper.				
	w/o Gear	%-ile	Gear	Delta		w/o Gear	%-ile	Gear	Delta
Weight	131.8	3	198	66.2	Weight	146.2	13	208	61.8
Stature	169.6	20	176.5	6.9	Stature	173.9	41	179.3	5.4
Sitting Height	88	19	91.1	3.1	Sitting Height	94.1	78	93.7	-0.4
Bideltoid Breadth	45.2	6	49.8	4.6	Bideltoid Breadth	47.4	25	50.7	3.3
Forearm to Forearm	51.4	24	55.5	4.1	Forearm to Forearm	49	9	56.9	7.9
Chest Depth	19.4	1	34.9	15.5	Chest Depth	24.4	55	29.6	5.2
Hip Breadth Sitting	34.1	15	-----	-----	Hip Breadth Sitting	35	27	-----	-----
Buttock-Knee Length	59.59	25	88.8	29.21	Buttock-Knee Length	57.9	10	93.5	35.6
Widest At Waist w/ Gear	-----	-----	51.3	-----	Widest At Waist w/ Gear	-----	-----	36	-----
Forward Observer					Forward Observer				
	w/o Gear	%-ile	Gear	Delta		w/o Gear	%-ile	Gear	Delta
Weight	153.8	22	213	59.2	Weight	134	4	199	65
Stature	168.2	14	172.7	4.5	Stature	168	13	174	6
Sitting Height	87.5	14	90.9	3.4	Sitting Height	90	35	91.1	1.1
Bideltoid Breadth	49	49	50	1	Bideltoid Breadth	47.7	30	49.8	2.1
Forearm to Forearm	52.4	33	53.2	0.8	Forearm to Forearm	49	9	55.3	6.3
Chest Depth	23	29	38.3	15.3	Chest Depth	21.9	14	29.5	7.6
Hip Breadth Sitting	38.2	75	-----	-----	Hip Breadth Sitting	35.9	40	-----	-----
Buttock-Knee Length	59.7	28	93	33.3	Buttock-Knee Length	59.1	21	96	36.9
Widest At Waist w/ Gear	-----	-----	41.4	-----	Widest At Waist w/ Gear	-----	-----	44.1	-----

60mm Gunner					60mm Asst. Gunner				
	w/o Gear	%-ile	Gear	Delta		w/o Gear	%-ile	Gear	Delta
Weight	176	59	238	62	Weight	140	8	197	57
Stature	173.4	39	177.7	4.3	Stature	168.6	15	176	7.4
Sitting Height	95.4	88	95.2	-0.2	Sitting Height	86.6	9	90.5	3.9
Bideloid Breadth	50.7	74	57.5	6.8	Bideloid Breadth	44	2	46.7	2.7
Forearm to Forearm	56.7	70	57	0.3	Forearm to Forearm	45.3	1	53.2	7.9
Chest Depth	24.8	61	36.8	12	Chest Depth	22.5	20	36.5	14
Hip Breadth Sitting	39.5	86	-----	-----	Hip Breadth Sitting	35.1	27	-----	-----
Buttock-Knee Length	61	44	93.5	32.5	Buttock-Knee Length	59.7	28	88.1	28.4
Widest At Waist w/ Gear	-----	-----	43.5	-----	Widest At Waist w/ Gear	-----	-----	48.8	-----
Rifleman					M240 Gunner				
	w/o Gear	%-ile	Gear	Delta		w/o Gear	%-ile	Gear	Delta
Weight	157	28	234	77	Weight	182.8	67	265	82.2
Stature	171.8	28	177.4	5.6	Stature	177	60	183.2	6.2
Sitting Height	91.2	47	93.8	2.6	Sitting Height	92.6	64	94.9	2.3
Bideloid Breadth	46.9	20	55.3	8.4	Bideloid Breadth	52.1	88	55	2.9
Forearm to Forearm	53	38	57.9	4.9	Forearm to Forearm	62	95	66.3	4.3
Chest Depth	24.5	55	33.6	9.1	Chest Depth	25.5	69	35.4	9.9
Hip Breadth Sitting	36.7	55	-----	-----	Hip Breadth Sitting	39.5	86	-----	-----
Buttock-Knee Length	59.6	26	92.8	33.2	Buttock-Knee Length	63.2	71	91.5	28.3
Widest At Waist w/ Gear	-----	-----	41.1	-----	Widest At Waist w/ Gear	-----	-----	40.4	-----

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## **Appendix D. Seat Width Data**

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This appendix appears in its original form, without editorial change.

Table D-1. Seat width data.

<b>Seat Spacing (Floor Width = 72.0") (Cabin Height = 78.0")</b>				<b>Comments</b>
<b>20 inches</b> (All Soldiers fit in seat space)				
How restrictive was body movement (Soldier sitting erect) for:	Very Restrictive	Somewhat Restrictive	Not Restrictive	
Torso Pivot	50%	39%	11%	-----
Lateral Torso Lean (left and right)	44%	28%	28%	-----
Arm movement (both arms)	39%	61%	0%	Could not put arms back against seat (3) Less freedom to move Can't move to side Can't reach gear on sides Slightly tight
Leg movement (both legs)	44%	39%	17%	Bag in the way (restricts movement)
Positioning of feet	28%	33%	39%	Can't move feet, but they fit.
Worn gear that had to be repositioned for seating: Canteen pouch – Ammo pocket on left side				
Problems with stowage of other gear (e.g., CLU): None reported				
Elapsed time for all Soldiers to ingress mockup and be seated = 20.0 seconds				
Elapsed time for all Soldiers to egress mockup = 11.0 seconds				
<b>22 inches</b> (All Soldiers fit in seat space)				
Torso Pivot	0%	22%	78%	-----
Lateral Torso Lean (left and right)	0%	28%	72%	-----
Arm movement (both arms)	22%	17%	61%	Right arm tight on canteen Tight on sides Tight with arms in
Leg movement (both legs)	17%	39%	44%	-----
Positioning of feet	11%	22%	67%	-----
Worn gear that had to be repositioned for seating: Rucksack had to be repositioned for four Soldiers				
Problems with stowage of other gear (e.g., CLU): None reported				
Elapsed time for all Soldiers to ingress mockup and be seated = 16.0 seconds				
Elapsed time for all Soldiers to egress mockup = 11.0 seconds				
<b>24 inches</b> (All Soldiers fit in seat space)				
Torso Pivot	0%	0%	100%	-----
Lateral Torso Lean (left and right)	0%	0%	100%	-----
Arm movement (both arms)	0%	22%	78%	-----
Leg movement (both legs)	0%	33%	67%	-----
Positioning of feet	0%	28%	72%	-----

Table D-1. Seat width data (continued).

<b>Seat Spacing (Floor Width = 72.0") (Cabin Height = 78.0")</b>				<b>Comments</b>
Worn gear that had to be repositioned for seating: Rucksack (4) and Medic bag (1)				
Problems with stowage of other gear (e.g., CLU): None reported				
Elapsed time for all Soldiers to ingress mockup and be seated = 19.0 seconds				
Elapsed time for all Soldiers to egress mockup = 13.0 seconds				
<b>26 inches</b> (All Soldiers fit in seat space)				
Torso Pivot	0%	6%	94%	-----
Lateral Torso Lean (left and right)	0%	11%	89%	-----
Arm movement (both arms)	0%	0%	100%	-----
Leg movement (both legs)	0%	6%	94%	-----
Positioning of feet	0%	0%	100%	-----
Worn gear that had to be repositioned for seating: None reported				
Problems with stowage of other gear (e.g., CLU): None reported				
<sup>a</sup> Elapsed time for all Soldiers to ingress mockup and be seated = 28.0 seconds				
Elapsed time for all Soldiers to egress mockup = 13.0 seconds				
Note: Order for seat spacing assessment was 26.0", 24.0", 22.0", and 20.0". Soldiers got more proficient with ingress and egress as assessment progressed due to practice effects.				



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## **Appendix E. Cabin Ceiling Height Data**

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This appendix appears in its original form, without editorial change.

Table E-1. Cabin ceiling height data.

<b>Cabin Ceiling Height 54.0 inches (68.0" Floor Width)</b>				<b>Comments</b>
Top of helmet touching cabin ceiling when seated?	Yes = 0%	No = 100%		-----
	Constantly	Often	Never	
How often did you have to bend torso and/or knees while ingressing	100%	0%	0%	-----
How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress	17%	11%	72%	-----
	Very Difficult	Somewhat Difficult	Not Difficult	
How difficult was it to carry and maneuver your gear during ingress due to ceiling height?	39%	50%	11%	Carried SAW differently, put out in front instead of carrying on chest.
Average elapsed time for all Soldiers to ingress mockup and be seated = 23.5 seconds Average elapsed time for all Soldiers to egress mockup = 21.3 seconds Times include ingress & egress via the two cabin doors and ramp and ramp only				
<b>Cabin Ceiling Height 60.0 inches (68.0" Floor Width)</b>				<b>Comments</b>
Top of helmet touching cabin ceiling when seated?	Yes = 0%	No = 100%		-----
	Constantly	Often	Never	
How often did you have to bend torso and/or knees while ingressing	94%	6%	0%	-----
How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress	17%	0%	83%	-----
	Very Difficult	Somewhat Difficult	Not Difficult	
How difficult was it to carry and maneuver your gear during ingress due to ceiling height?	28%	39%	33%	Carried SAW differently, put out in front instead of carrying on chest.
Average elapsed time for all Soldiers to ingress mockup and be seated = 18.3 seconds Average elapsed time for all Soldiers to egress mockup = 16.8 seconds Times include ingress & egress via the two cabin doors and ramp and ramp only				

Table E-2. Cabin ceiling height data (continued).

<b>Cabin Ceiling Height 66.0 inches (68.0" Floor Width)</b>				<b>Comments</b>
Top of helmet touching cabin ceiling when seated?	Yes = 0%	No = 100%		-----
	Constantly	Often	Never	
How often did you have to bend torso and/or knees while ingressing	11%	67%	22%	-----
How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress	0%	11%	89%	Almost tripped
	Very Difficult	Somewhat Difficult	Not Difficult	
How difficult was it to carry and maneuver your gear during ingress due to ceiling height?	6%	33%	61%	Had to duck with M240 Ammo
Average elapsed time for all Soldiers to ingress mockup and be seated = 16.5 seconds Average elapsed time for all Soldiers to egress mockup = 15.8 seconds Times include ingress & egress via the two cabin doors and ramp and ramp only				
<b>Cabin Ceiling Height 72.0 inches (68.0" Floor Width)</b>				<b>Comments</b>
Top of helmet touching cabin ceiling when seated?	Yes = 0%	No = 100%		-----
	Constantly	Often	Never	
How often did you have to bend torso and/or knees while ingressing	6%	6%	88%	-----
How often did you have to place hands on other Soldiers or cabin interior to maintain balance during ingress	0%	0%	100%	-----
	Very Difficult	Somewhat Difficult	Not Difficult	
How difficult was it to carry and maneuver your gear during ingress due to ceiling height?	0%	0%	100%	
Average elapsed time for all Soldiers to ingress mockup and be seated = 16.3 seconds Average elapsed time for all Soldiers to egress mockup = 14.0 seconds Times include ingress & egress via the two cabin doors and ramp and ramp only				

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## **Appendix F. Ingress and Egress Time Data**

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This appendix appears in its original form, without editorial change.



Emergency Egress Only one egress exit per trial 60 second time requirement for all passengers to egress			
<u>Door/Ramp</u>	Number of troops	Ceiling Height	Egress Time
Left Front Door	18	60	19
Left Front Door	14	60	15
Left Front Door	9	60	12
Left Front Door	18	66	20
Left Front Door	14	66	15
Left Front Door	9	66	11
Ramp	18	60	15
Ramp	14	60	11
Ramp	9	60	7
Ramp	18	66	14
Ramp	14	66	10
Ramp	9	66	7
Average emergency egress time = 13 seconds Range = 7 - 20 seconds Standard deviation = 4 seconds			

Normal Ingress and Egress Times for All Trials  
Both mockup doors and ramp used during all ingress/egress unless otherwise listed  
(i.e., 'RAMP Only')

Seat Spacing Width	Time in Seconds		Cabin Height
72.0" Width	Ingress	Egress	
20in Spacing	20	11	72
22in Spacing	16	11	72
24in Spacing	19	13	72
26in Spacing	28	13	72

V-22 Bench Width Assessment

	Ingress	Egress
	22	12

Cabin Height Assessment (68.0")

	Ingress	Egress
54in Height	23	22
54in Height (RAMP Only)	25	23
54in Height	23	19
54in Height (RAMP Only)	23	21
60in Height	21	16
60in Height (RAMP Only)	18	18
60in Height	17	15
60in Height (RAMP Only)	17	18
66in Height	18	16
66in Height (RAMP Only)	17	17
66in Height	16	14
66in Height (RAMP Only)	15	16
72in Height	17	14
72in Height (RAMP Only)	18	16
72in Height	16	12
72in Height (RAMP Only)	14	14
78in Height	14	11
78in Height (RAMP Only)	12	13

Average ingress time = 19 seconds

Range = 12 - 28 seconds

Standard deviation = 3.9 seconds

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Average egress time = 15 seconds

Range = 11 - 23 seconds

Standard deviation = 3.5 seconds

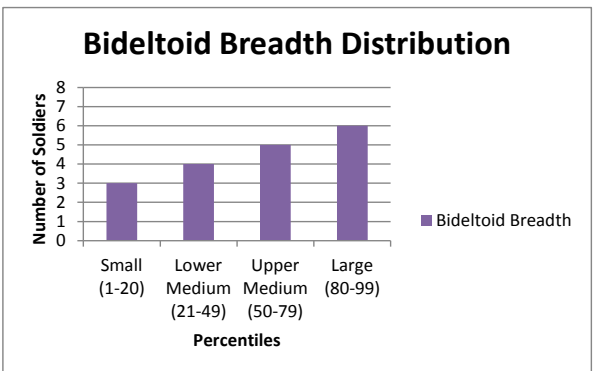
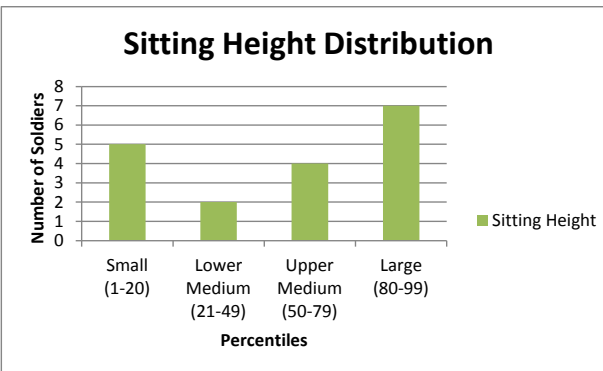
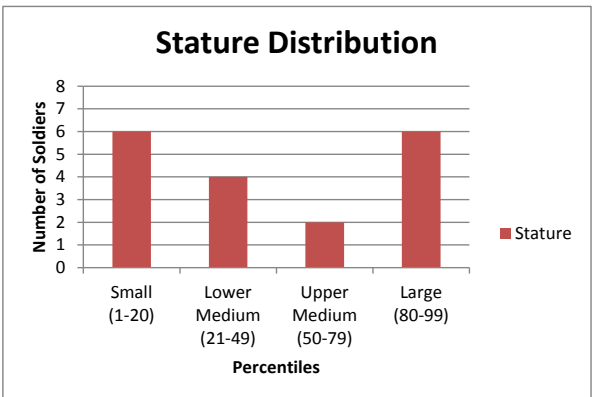
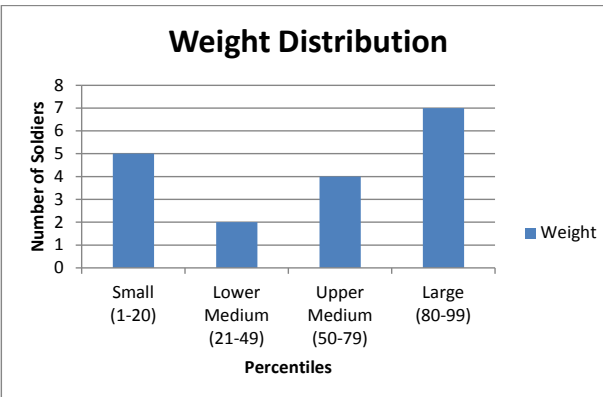
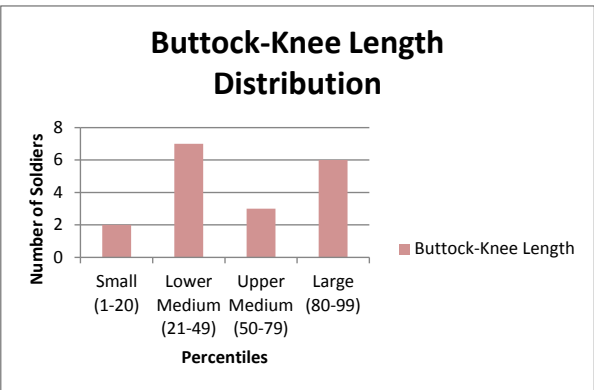
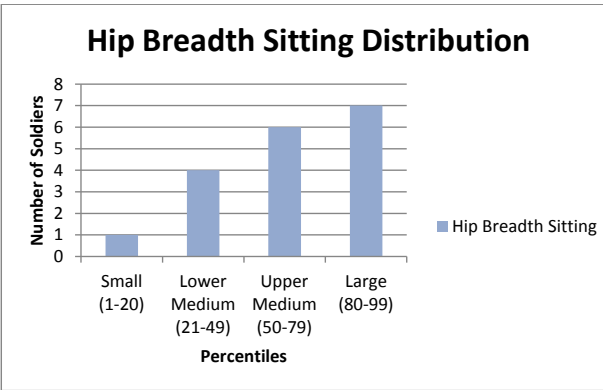
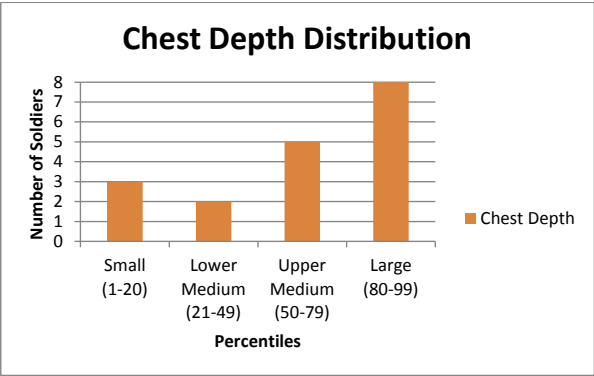
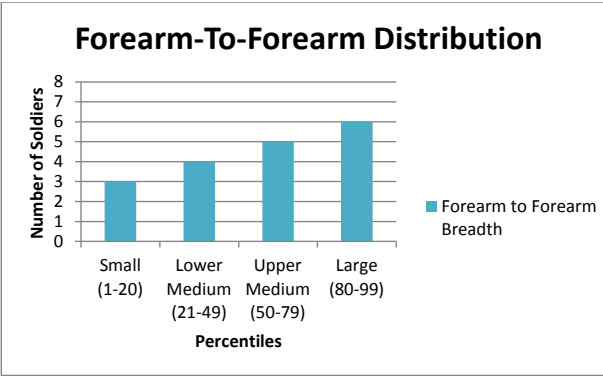
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## **Appendix G. Anthropometric Distribution for Measurements**

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